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LARGE-ARRAY SIGNAL AND NOISE ANALYSIS

Special Scientific Report No. 15

TRAVELTIME ANALYSIS FOR LASA

Prepared by

Peter R. Fenner

Frank H. Binder, Program Manager

TEXAS INSTRUMENTS INCORPORATED

Science Services Division
P.O. Box 5621
Dallas, Texas 75222

Contract No. AF 33(657)-16678

Prepared for

AIR FORCE TECHNICAL APPLICATIONS CENTER
Washington, D.C. 20333

Sponsored by

ADVANCED RESEARCH PROJECTS AGENCY
ARPA Order No. 599
AFTAC Project No. VT/6707

20 December 1967

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SECTION I

INTRODUCTION AND SUMMARY

This special report investigates several practical aspects of generating high-resolution wavenumber spectra using subarray outputs of the Montana LASA. The following are questions of particular interest:

- Variability of traveltime anomalies as a function of wavenumber
- Spectral window effect on crosspower estimates due to moveout across the array
- Tradeoffs involved in a finite length transform of array data

These questions are investigated with either easily available data or simple models of the situation being considered. A general understanding of the type of constraints encountered, rather than an exact mathematical treatment of each situation, is desired.

A. TRAVELTIME ANOMALY VARIATIONS

Variations in traveltime anomalies were analyzed using punched cards obtained from the Seismic Data Laboratory, Alexandria, Virginia. The punched cards contained the date, time, latitude, longitude, and arrival time recorded at each LASA subarray for 384 teleseismic events.

A map of the world, as seen teleseismically (in $\vec{k}$-space) from LASA, was overlaid with a grid containing 58 divisions in the north-south direction and 48 divisions in the east-west direction. The edges of the grid were tangent to the circle corresponding to a 10-km/sec velocity across LASA. Each of the 384 events was assigned to the block on the grid containing its epicenter. The average traveltime residual (anomaly) for each subarray was computed for each block containing one or more events.

Several adjacent blocks were compared using the mean residual computed for each subarray. The following general characteristics were observed in this traveltime anomaly analysis:

- Variations in traveltime residuals for adjacent blocks were of the order of the standard deviation of the data in each block
- Variations between blocks in a 3- to 5-block region were greatest for events coming from South America
- Only 113 blocks contained events; of these, only 25 had five or more events
- Subarrays on the E and F rings generally had larger means and standard deviations in their residuals than did the inner subarrays

From these observations, the data appeared to be insufficient to define residual correction functions covering the wavenumber regions of interest. Until sufficient data are available to define such functions with reasonable confidence, no generalized attempt will be made to correct the wavenumber spectra calculations for traveltime anomalies.

B. MOVEOUT WINDOW ANALYSIS

A simple single-frequency plane-wave model was used to analyze the spectral window due to a "boxcar" smoothing function applied to a crosspower spectra. When a crosspower spectrum is formed from two finite time series, some type of smoothing is always present. The spectral window resulting from crosspower smoothing is a function of both the time-series length (T) and the signal moveout (τ_{ij}, the signal traveltime from the i^{th} to the j^{th} sensor). The spectral window function for this case is

$$H(\Delta f, \tau_{ij}) = \frac{\sin(\pi \Delta f \tau_{ij})}{(\pi \Delta f \tau_{ij})}$$

where Δf is the width of the "boxcar" smoothing function. The smallest Δf (least smoothing) obtainable with a time series of length T is

$$\Delta f = \frac{1}{T}$$

This results in the following relationship between data length T, the moveout between channels τ_{ij}, and the magnitude of the crosspower estimate Φ:

$$\Phi_{ij} = \frac{\sin\left(\pi \frac{\tau_{ij}}{T}\right)}{\left(\pi \frac{\tau_{ij}}{T}\right)} \Phi_{ij}^{T}$$

where Φ_{ij}^{T} is the true crosspower between channels i and j. The crosspower estimate will then have a magnitude of 90 percent of the true crosspower magnitude when the ratio $\frac{\tau_{ij}}{T} \leq 0.25$.

Transform gate lengths should be about four times the largest expected moveout across the array if crosspower estimates between channels are to be meaningful.

The importance of this criterion is apparent when more than one signal is present. In the case of two plane wavefronts of different apparent velocity, the phase of the crosspower spectrum has an ambiguous interpretation. This ambiguity can be resolved if the crosspower magnitude estimates between pairs of sensors are close to the true crosspower magnitudes.

Currently, the effect on f-$\vec{k}$ spectra of normalizing the crosspower estimates in a multiple-signal environment is not fully understood; this aspect of computing high-resolution f-$\vec{k}$ spectra is the object of further investigation.

C. TRADEOFF IN FINITE-LENGTH TRANSFORMS OF ARRAY DATA

As the aperture of a seismic array increases, the data transform gate must be correspondingly increased to keep the spectral window from deteriorating the information. This increase in transform gate reduces the effective signal-to-noise ratio when the signals of interest are transients within the gate. This decrease in signal-to-noise ratio can be offset by adding more sensors as the aperture is increased, assuming that signals of the same minimum apparent velocity are applicable to both arrays. Change in signal-to-noise ratio due to change in array diameter from d_k to d_ℓ and change in number of sensors from N_k to N_ℓ can be expressed as

$$H_{\ell,k} = \left(\frac{d_k}{d_\ell}\right) \left(\frac{N_\ell}{N_k}\right)$$

This formula indicates that doubling the number of sensors and doubling the aperture will not change the signal-to-noise improvement expected in frequency wavenumber spectra calculations. At LASA, the E and F rings successively double the aperture of the previous array but add only four sensors each. The available signal-to-noise improvement is then decreased when these two outer rings are included in frequency-wavenumber spectra calculations.

D. SUMMARY

From this section, it is concluded that current data are insufficient to adequately describe the amplitude, traveltime, and waveform anomalies at LASA. Additionally, subarrays on the E and F rings will not be used in frequency-wavenumber spectra evaluation. These subarrays will be used for teleseismic event detection using the current LASA detection scheme.

SECTION II

COMPARISON OF TRAVELTIME RESIDUALS

The assumption of space stationarity necessary for computing meaningful wavenumber spectra may not prove to be a valid assumption for large-diameter arrays such as LASA. Departures from the assumed plane wavefront of constant waveform moving at constant velocity may be due to two primary factors: the first is instrument response variations and should be independent of wavenumber; the second is the effect introduced by different ray paths and different seismometer-to-earth couplings. Upper mantle inhomogenieties, due to variations in thickness and composition, will probably be a function of wavenumber (Appendix B).

At least part of the second factor can be determined empirically by computing the residuals caused by the difference between theoretical and actual arrival times at each subarray for a teleseismic P-wave from an event of known epicenter. These computed time residuals yield the phase corrections used when computing the portion of a wavenumber spectra corresponding to that epicentral location. In this report, there is no attempt to analyze amplitude anomalies at LASA.

A. WAVENUMBER GRID FOR LASA

Standard wavenumber spectra computed by Texas Instruments Incorporated are printed out on an alphabetically coded grid. This produces a square area on an IBM-computer printed page. Consistent with this format, a map of the world as seen teleseismically from LASA was overlaid with a 58-row by 48-column grid. Rows were aligned in the east-west direction. The grid's edges were tangent to the circle representing the loci of epicenters which would theoretically produce a 10-km/sec signal velocity across LASA. Figure II-1 shows the wavenumber grid for LASA.

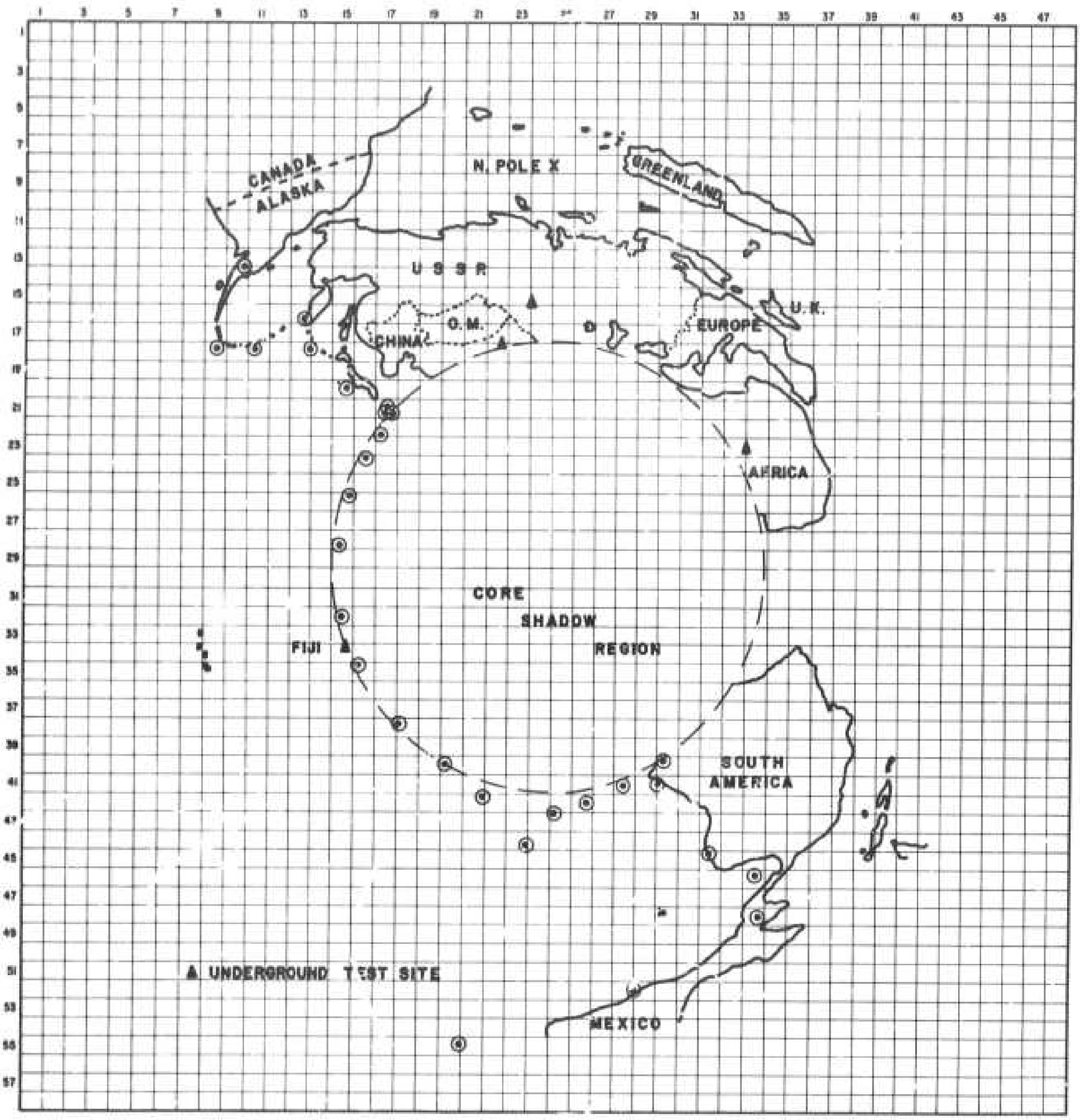

Figure II-1. Wavenumber Grid for LASA

B. LASA TRAVELTIME ANOMALY COMPUTATIONS FOR BLOCKS OF WAVENUMBER SPACE

The wavenumber plane is divided into a grid of equal-sized blocks to correct for traveltime anomalies when computing frequency-wavenumber spectra from LASA data. Since different blocks of the same size in wavenumber space cover different sizes of epicentral area, a special computation is needed to determine the anomalies for a particular block from the available anomaly information.

The TI standard wavenumber printout is on an alphabetically coded grid; the wavenumber plane is divided into 58 blocks in a north-south direction (k_y) and into 48 blocks in the east-west direction (k_x). The edges of the grid are tangent to a minimum-velocity circle of 10 km/sec. A particular block in the grid is always associated with the same area on the surface of the earth as seen from the Montana LASA.

The data used in the tabulation include 384 events with date, latitude, longitude, and arrival time (hours, minutes, and seconds) for each subarray on punched cards. A program has been written to read the data and perform the following calculations.

- Epicentral angle (Δ) and azimuth of each event for each subarray are calculated using the location of the subarray and the following formulas

  Event epicentral angle

$$\Delta = \text{arc cos } (D1)$$

where

$$D1 = \cos(B1) \cdot \cos(C1) + \sin(B1) \cdot \sin(C1) \cdot \cos(A1)$$

and

$$A1 = \text{(event long.)} + \text{(subarray long.)}$$

$$B1 = 90.0^\circ - \text{(event lat.)}$$

$$C1 = 90.0^\circ - \text{(subarray lat.)}$$

Azimuth of event

Azimuth = Az (event in NE quadrant)

Azimuth = 180° - Az (event in SE quadrant)

Azimuth = 180° + Az (event in SW quadrant)

Azimuth = 360° - Az (event in NW quadrant)

where

$$Az = \left| \text{arc sin } (E1) \right|$$

and

$$E1 = \frac{\sin (A1) \sin (B1)}{\sin (\Delta)}$$

- The expected traveltime from each event to each subarray is determined using a second-order interpolation between the 1° increments given in the Jeffreys-Bullen table

- The traveltime anomaly of each event for each subarray relative to subarray A0 is calculated using the formula

$$A_j = \left(T_j - H_j\right) - \left(T_{A0} - H_{A0}\right)$$

where

T_j is observed arrival time for j^{th} subarray

H_j is computed traveltime to j^{th} subarray

- The horizontal velocity of each event at subarray A0 is interpolated from a table using epicentral angle Δ

- The block in wavenumber space containing an event is computed using the horizontal velocity and azimuth for the event

- After the preceding five steps have been completed for each event, the wavenumber space is searched block by block and, if one or more events are found in a block, the traveltime anomalies, average anomaly (AVERAGE), and standard deviation (SD) are computed for each subarray. For the j^{th} subarray,

$$\text{AVERAGE} = \frac{1}{N_j} \sum_{\ell=1}^{N_j} A_j^{\ell}$$

$$\text{SD} = \left[\frac{1}{N-1} \sum_{j=1}^{N} \left(A_j - \text{AVERAGE} \right)^2 \right]^{1/2}$$

where

N_j is number of events in j^{th} block

A_j^{ℓ} is traveltime residual for ℓ^{th} event in j^{th} block

Table II-1 summarizes the distribution of the 384 usable events over the 113 blocks within which their epicenters are located. The calculations do not use 22 of the 406 events processed, because the A0 arrival time was not determined. Figure II-2 presents distribution of the events over the wavenumber blocks.

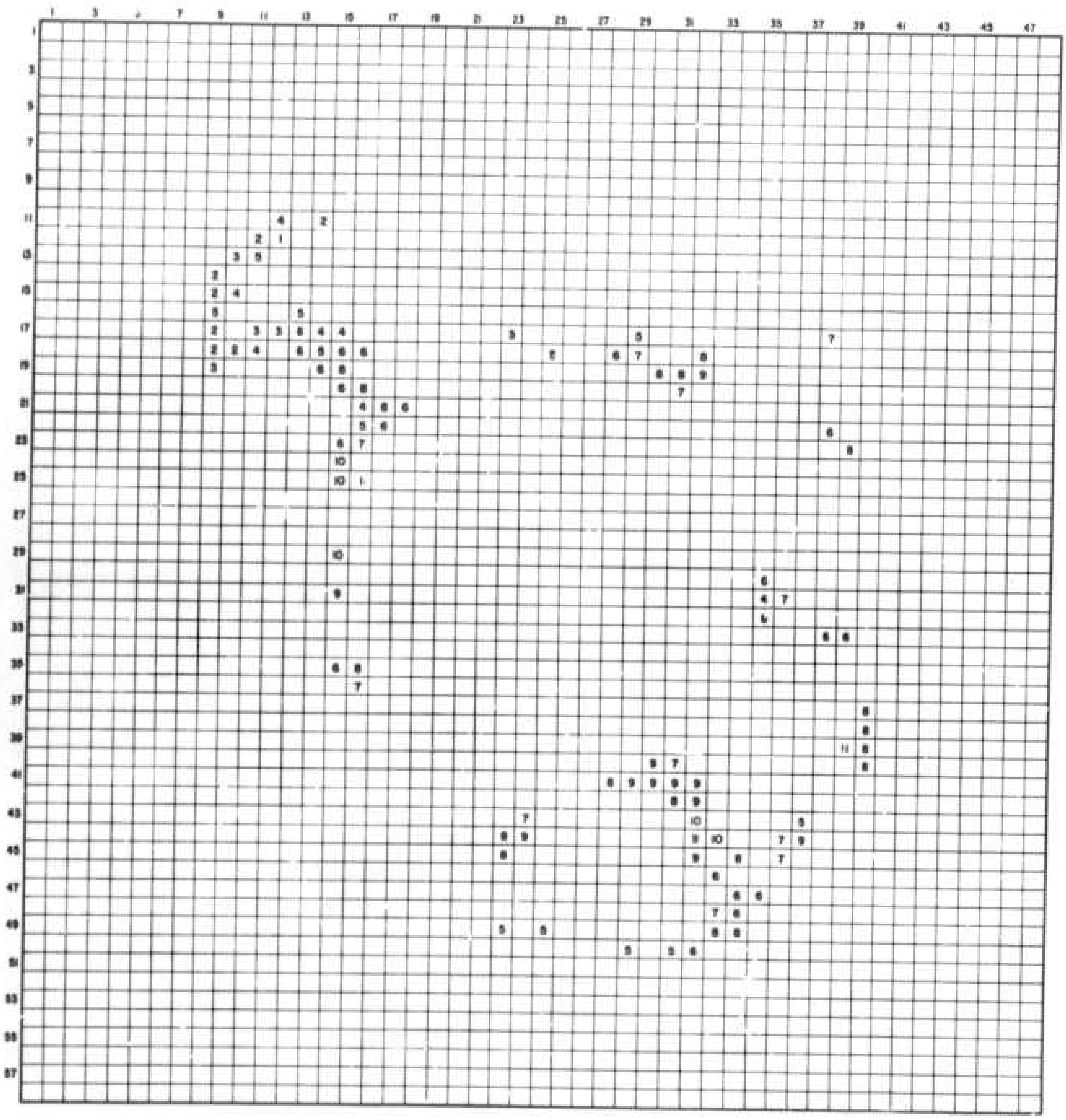

Figure II-2. Number of Events in Each Block

Table II-1

SUMMARY OF DISTRIBUTION OF USABLE EVENTS

No. of Events/Block	No. of Blocks with Given No. of Events	No. of Events
1	45	45
2	20	40
3	14	42
4	9	36
5	5	25
6	5	30
7	6	42
8	2	16
9	1	9
10	1	10
12	1	12
16	2	32
17	1	17
28	1	28
Totals	113	384

C. COMPARISONS OF TRAVELTIME RESIDUALS

Comparison of the traveltime residuals computed for the teleseismic grid (subsection B) was made using blocks in the Kazakh-Hindu Kush, South American, and Japan-Alaskan regions to determine the

- Difference in each subarray residual for adjacent blocks
- Difference in each subarray residual at 2- and 3-block distances
- Difference over a 3-block region
- Difference in widely separated blocks of the same general region
- Comparison of block residuals to previously computed residuals for the region of interest
- Portion of the time residual due to the different elevation of the LASA subarrays

These comparisons are presented in Tables II-2, II-3, and II-4. The Kazakh-Hindu Kush and South American comparisons were made to determine the differences between time residuals computed for adjacent blocks in wavenumber space and previously computed time residuals for these two regions. Two sets of previously computed time residuals are compared to the set computed for this report. One set was composed of time residuals computed by TI for the Large-Array Signal and Noise Analysis Special Report No. 1* and the other consisted of residuals published in an SDL report.** Many of the events used in the SDL residual calculations were included in the data set used in the calculations for this report. The TI Special Scientific Report No. 1 residuals were calculated from a different set of events.

1. Kazakh-Hindu Kush Comparison

Only one event in the data card library had an epicenter located in block 17,23 — the Kazakh region of the USSR. Residuals computed for this event compared well with the SDL-computed residuals; this was expected, since the SDL Kazakh event ensemble contained this event. Residuals computed for block 18,25 — Hindu Kush region — were identical with the SDL-computed residuals due to a nearly identical data set. Block 18,25 residuals agree much better with the Kazakh residuals computed for TI Special Scientific Report No. 1 than do the residuals for block 17,23; this indicates that the previous TI-calculated residuals contained a number of events from the Hindu Kush region.

* Texas Instruments Incorporated, 1967: A Study of the Relative Capability of Large and Small Seismic Arrays for Event Identification, Large-Array Signal and Noise Analysis, Spec. Rpt. No. 1, Contract AF 33(657)-16678, 20 Apr.

** Seismic Data Laboratory, 1966: LASA Traveltime Anomalies for Various Epicentral Regions, ARPA Order No. 624, 13 Sep.

Table II-2

KAZAKH COMPARISON

	Time Residuals				Difference of Residuals						
Subarray	Block 17,23	Block 18,25	TI Rpt. No. 1 (appendix)	SDL Report	Max.-to-Min. Difference	Blocks 17,23 18,25	Block 17,23 TI No. 1	Block 17,23 SDL	Block 18,25 TI No. 1	Block 18,25 SDL Kazakh	Block 18,25 SDL Hindu Kush
A0	—	—	—	—	—	—	—	—	—	—	—
B1	.00	.01	-.04	-.06	.07	.01	.04	.06	.05	.07	.00
B2	.00	.05	.08	-.04	.12	.05	.08	.04	.02	.09	.01
B3	.00	.02	.05	.04	.03	.02	.05	.04	.03	.02	.00
B4	.00	.04	.11	.05	.07	.04	.11	.05	.07	.01	.00
C1	-.08	.03	.07	-.04	.15	.11	.15	.04	.04	.07	.00
C2	-.01	.03	.03	-.10	.13	.04	.04	.09	.00	.13	.00
C3	.01	.15	.16	.02	.15	.14	.15	.01	.01	.13	.00
C4	.09	.20	.25	.13	.16	.11	.16	.04	.05	.07	.00
D1	—	-.03	-.19	-.07	.16	.03	.19	.07	.16	.04	.00
D2	.18	.29	.33	.17	.16	.11	.15	.01	.04	.12	.02
D3	.30	.38	.40	.30	.10	.08	.10	.00	.02	.08	.01
D4	.03	.13	.10	.03	.13	.10	.07	.00	.03	.10	.01
E1	-.16	-.11	-.03	-.17	.14	.05	.13	.01	.09	.06	.01
E2	.09	.28	.26	.11	.15	.19	.17	.02	.02	.17	.01
E3	.52	.59	.67	.51	.16	.07	.15	.01	.08	.08	.00
E4	.53	.71	.65	.64	.18	.18	.12	.11	.06	.07	.03
F1	-.18	-.09	-.07	-.11	.09	.09	.11	.07	.02	.02	.02
F2	.48	.68	.48	.48	.20	.20	.00	.00	.20	.20	.01
F3	.63	.32	.70	.67	.19	.19	.07	.04	.08	.15	.00
F4	.50	.47	.56	.47	.09	.03	.06	.03	.09	.00	.01

Table II-3

SOUTH AMERICAN COMPARISON

	Time Residuals				Difference of Residuals							
Subarray	Block 42,32	Block 41,30	TI Rpt. No. 1 South America	SDL South America	Max.-to-Min. Difference	Block 41,31	Blocks 41,30 41,31	Blocks 41,31 42,32	Blocks 41,30 41,31 42,32	Block 41,31 SDL	Block 41,31 TI Rpt. No. 1	Blocks 41,31 44,37
A0	—	—	—	—	—	—	—	—	—	—	—	—
B1	-.01	-.01	-.11	-.02	.10	-.02	.01	.01	.01	.00	.09	.01
B2	.17	.14	.14	.16	.05	.19	.05	.02	.05	.03	.05	.10
B3	-.01	.04	.11	-.01	.12	.01	.03	.00	.05	.00	.10	.06
B4	-.23	-.24	-.07	-.19	.17	-.18	.06	.05	.06	.01	.11	.05
C1	-.31	-.22	-.21	-.28	.10	-.26	.04	.05	.09	.02	.05	.03
C2	.06	.11	.11	.09	.05	.11	.00	.05	.05	.02	.00	.08
C3	.13	.19	.23	.18	.10	.19	.00	.06	.06	.01	.04	.09
C4	-.30	-.22	-.17	-.24	.13	-.23	.01	.07	.08	.01	.06	.03
D1	-.17	-.17	-.14	-.19	.05	-.16	.01	.01	.01	.03	.02	.10
D2	.29	.28	.24	.33	.09	.32	.04	.03	.04	.01	.08	.16
D3	-.13	.03	.03	-.02	.16	-.03	.03	.10	.16	.01	.00	.09
D4	-.62	-.38	-.40	-.46	.22	-.44	.06	.18	.24	.02	.04	.25
E1	-.58	-.26	-.41	-.42	.32	-.41	.15	.17	.32	.01	.00	44
E2	.32	.39	.41	.40	.09	.41	.02	.09	.09	.01	.00	.19
E3	-.11	.03	.03	-.05	.14	-.05	.08	.06	.14	.00	.02	.10
E4	-.43	.30	-.31	-.33	.13	-.38	.08	.05	.13	.05	.07	.01
F1	-.43	-.23	-.50	-.32	.27	-.32	.09	.09	.20	.00	.18	.49
F2	.14	.15	.06	.15	.09	.15	.00	.01	.01	.00	.09	.05
F3	-.08	-.02	-.10	-.04	.08	-.04	.02	.04	.06	.00	.06	.02
F4	-.10	.09	-.26	.02	.35	.03	.06	.13	.19	.01	.29	.57

Table II-4

RELATIVE ELEVATION OF SUBARRAYS WITH RESPECT TO A0

Subarray	Elevation* (meters)	Max. Time (msec at 4 km/sec)	Difference between 17, 9 and 21, 18 (in msec)
A0	—	—	—
B1	+ 10.0	- 2.5	130
B2	- 50.5	12.6	140
B3	- 21.9	5.5	- 10
B4	- 27.8	7.0	140
C1	- 26.4	6.6	150
C2	+ 34.0	- 8.5	190
C3	- 62.0	15.5	70
C4	+ 19.6	- 4.9	120
D1	+ 14.2	- 3.5	300
D2	- 83.7	20.9	80
D3	+ 55.1	-13.8	190
D4	- 30.8	7.5	130
E1	- 58.9	14.7	180
E2	-134.6	33.6	190
E3	+ 16.9	- 4.2	70
E4	+ 58.5	-14.6	10
F1	- 4.3	1.1	- 30
F2	+ 9.9	- 2.5	-160
F3	+ 92.9	-23.2	150
F4	- 37.0	9.2	280

*+ is above A0

In comparing the residuals for block 17,23 with those for block 18,25, close agreement was found for only six of the 21 subarrays; the remaining 15 subarrays differed by at least one LASA sample period (50 msec). F4 was the only subarray in the E and F rings differing by less than 50 msec, indicating that traveltime residuals for Asia changed significantly over a 2- to 3-block region. Traveltime residuals for the E and F rings generally have a larger mean and variance than the residuals computed for the lower rings.

2. South American Comparison

Of the four wavenumber blocks used for comparison in the South American region, three were adjacent to each other and covered the Northern Argentina-Chile border region. The fourth was seven blocks away and covered part of the Venezuelan coast.

Block 41,21 in the center of the 3-block group showed extremely close correspondence with the SDL time residuals computed for this region; this was expected, since most of the events used were common to both computations. Block 41,21 did not correspond as well with blocks 41,30 or 42,32 as it did with the SDL Northern Argentina-Chile residuals. A similar change in traveltime residuals for adjacent epicentral regions in South America can be observed in the SDL-computed traveltime residuals. The differences in traveltime residuals within the 3-block group were almost as great as the differences between blocks 41,31 and 44,37, which were about six blocks apart. This indicates degradation in wavenumber resolution when several adjacent blocks within the South American region are corrected with the same set of traveltime residuals.

3. Traveltime Residuals Due to Subarray Elevation

As shown in Figure II-3, the number of subarrays in a block needing a traveltime correction decreases as the wavenumber increases.

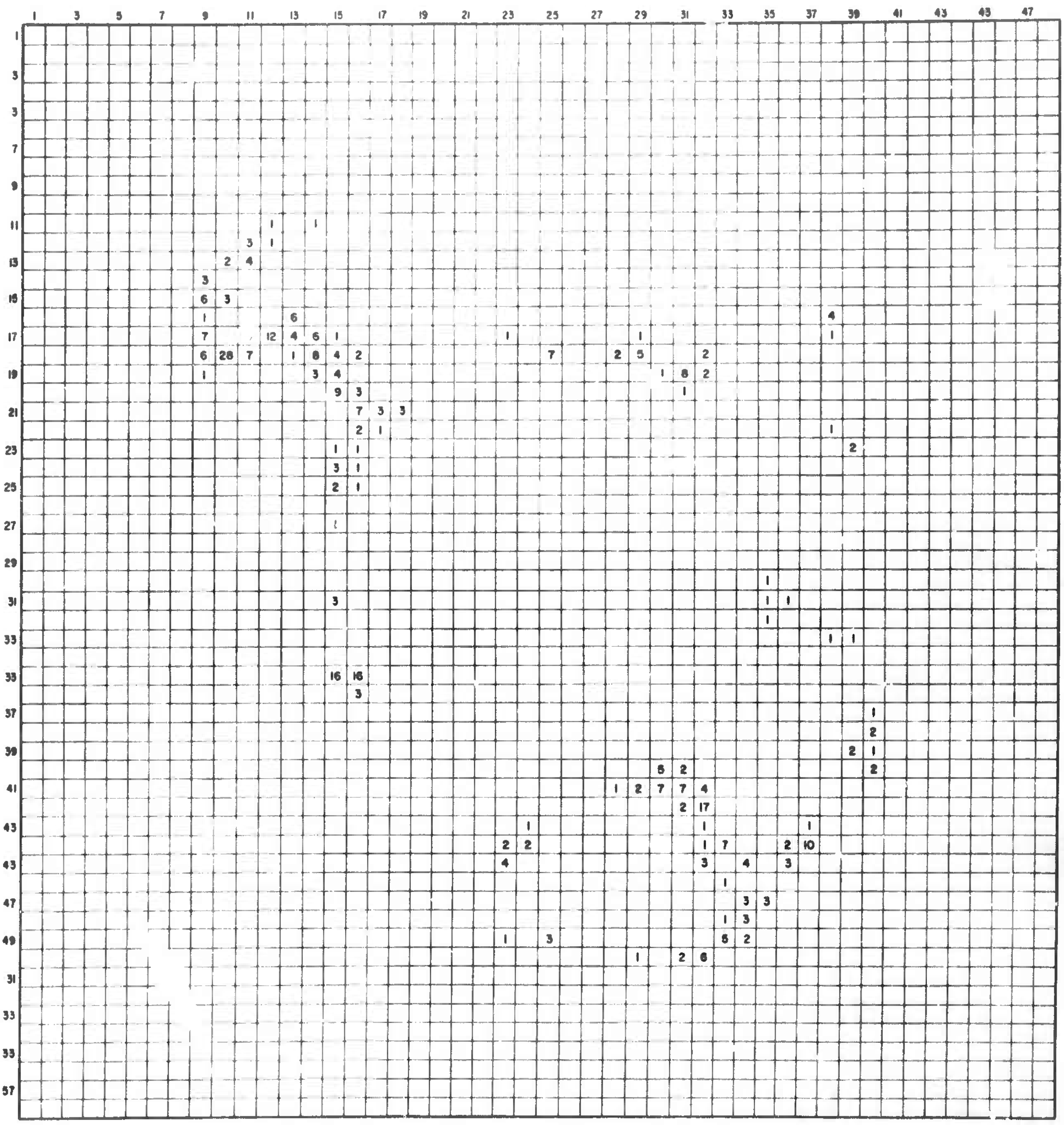

Figure II-3. Number of Subarrays Needing Correction (B, C, and D Rings)

This indicates that events from distant epicenters require traveltime corrections for a greater number of subarrays than do events of closer epicenter, even though the distant events have a higher apparent velocity across the array. It was thought that this phenomenon might be explained by a difference in elevation between each subarray and the reference subarray.

Table II-4 summarizes the differences in elevation and the corresponding traveltimes in a medium with a 4-km/sec propagation velocity. These computed traveltimes are compared with the difference in traveltime residuals computed for blocks 17, 9 and 21, 18. The theoretical traveltime anomalies due to elevation are insignificant compared with anomaly differences actually experienced.

D. OBSERVATIONS IN USING ANOMALIES

Experience in computing high-resolution wavenumber spectra at LASA indicates that regional corrections for traveltime anomalies are usually needed to detect a signal using the full LASA. The computed subarray spectra usually can detect signals without anomaly corrections. Generally, the effect of traveltime anomalies on intermediate-size arrays (diameters from 20 to 60 km) cannot be evaluated using the currently available anomaly data. These effects will be investigated using data from the E3 extended subarray and from a LASA configuration consisting of the A, B, C, and D rings of subarray outputs.

E. CONCLUSIONS ABOUT ANOMALIES

From the traveltime anomalies investigated, the following general observations were made:

- Variations in traveltime residuals for adjacent blocks were of the order of the standard deviation of the data in each block

- Variations between blocks in a 3- to 5-block region were greatest for events coming from South America
- Differences in subarray residuals for blocks separated by three or more blocks were greater than the standard deviation of the data in each block
- Only 113 blocks contained events and, of these, only 25 had five or more events
- Subarrays in the LASA E and F rings generally had larger means and standard deviations in their calculated residuals than did the inner-ring subarrays
- Comparison with SDL was very good due to common data
- Relative differences in subarray elevation had no significant effect on the traveltime residuals
- Comparison with previous TI-computed residuals was not good due to the large areas used in previous calculations.

Variability of the mean traveltime residuals was small enough to permit computation of average residuals for multiple block regions. This was confirmed in Special Scientific Report No. 1 where a large region was considered when computing residuals.*

The data currently available are inadequate for the design of a reasonable scheme to correct wavenumber spectra calculations for traveltime anomalies. This was apparent from the wavenumber distribution of the available events. Large areas of interest completely lacked events. Before any reasonable correction scheme can be devised, more higher-quality data must be available.

*Op cit

If the wavenumber spectra calculations are not corrected for traveltime anomalies, the subarrays on the LASA E and F rings should not be included in the calculations due to their generally large traveltime residuals. Other arguments for not including these subarrays when calculating wavenumber spectra are presented in the following sections.

SECTION III
SMOOTHING MOVEOUT ANALYSIS

High-resolution wavenumber spectra are generated by using a discrete Fourier transform such as the Cooley-Tukey algorithm to transform the time-domain data to the frequency domain before estimating the auto- and crosspower spectra. This section uses simple models to analyze the spectral window and the effective signal-to-noise improvement experienced when generating high-resolution spectra from LASA data.

By estimating the crosspower spectrum of two sensors in a seismic array from the direct Fourier transform of the individual time traces, a spectral window effect is produced in the estimate. Under the simple assumptions of uniform plane-wave propagation across the array and a boxcar smoothing in the direct transform, this spectral window is expressed as

$$\frac{\sin\left(\pi \frac{t_{ij}}{T}\right)}{\left(\pi \frac{t_{ij}}{T}\right)} \qquad (3\text{-}1)$$

where T is the length of the data trace transformed and t_{ij} is the moveout between the i^{th} and j^{th} channel. If the energy across the smoothing window is uniformly distributed, the phase of the crosspower spectrum is unaffected by the spectral window. This interpretation (i.e., processing) of a crosspower spectrum using only the phase information becomes ambiguous when there is more than one plane wave.

To reduce the spectral window for a fixed maximum expected moveout requires that the transform gate length be increased. Similarly, to maintain the same spectral window for an increased maximum moveout also requires an increased tran form gate length. This increase in transform

gate length reduces the effective signal-to-noise ratio for the transient seismic signal being considered. In both cases, the decrease in effective signal-to-noise ratio can be offset by adding more sensors within the array.

Although the following development treats the simple cases just discussed, the results are helpful in eliminating gross errors when generating crosspower estimates from direct transforms.

A. DEVELOPMENT OF WINDOW FUNCTION

Consider two sensors S_i and S_j separated by distance d_{ij} in a seismic array. When a uniform plane wave propagates across the array with an apparent velocity of v_{ij} along d_{ij}, moveout (traveltime) t_{ij} between S_i and S_j is

$$t_{ij} = \frac{d_{ij}}{v_{ij}} \tag{3-2}$$

We let θ_p be the angle made by the line d_{ij} with the direction of propagation of the plane wave. Then, for a plane wave with velocity v_p, apparent velocity v_{ij} is

$$v_{ij} = \frac{v_p}{\cos \theta_p} \tag{3-3}$$

Moveout t_{ij} is then

$$t_{ij} = \frac{d_{ij}}{v_p} \cos \theta_p \tag{3-4}$$

For a particular v_p, the largest moveout which can be experienced in a multisensor array occurs between sensors with the widest separation when the wavefronts are propagating in the direction of separation (i.e., $\theta_p = 0$). Later, we will show that the largest expected moveout constrains the data processing.

The crosspower spectrum between S_i and S_j is then

$$\phi_{ij}(f) = M \exp (J\, 2\pi\, f\, t_{ij}) \tag{3-5}$$

Here, we assume that the estimation process can be represented as a boxcar smoothing applied over an interval

$$f_a \le f_o \le f_b \tag{3-6}$$

The estimated crosspower at frequency f_o is

$$\overline{\phi}_{ij} = \frac{M}{(f_b - f_a)} \int_{f_a}^{f_b} \exp (J\, 2\pi\, f\, t_{ij})\, df \tag{3-7}$$

Carrying out the indicated integration gives

$$\overline{\phi}_{ij} = \frac{-JM}{2\pi\, t_{ij}\, (f_b - f_a)} \left[\exp (J\, 2\pi\, t_{ij} f_b) - \exp (J\, 2\pi\, t_{ij} f_a)\right] \tag{3-8}$$

Then, the real and imaginary parts of Equation 3-8 are

$$\mathrm{Re}\, \overline{\phi}_{ij} = \frac{M}{2\pi\, t_{ij}\, (f_b - f_a)} \left[\sin 2\pi\, t_{ij}\, f_b - \sin 2\pi\, t_{ij}\, f_a\right] \tag{3-9}$$

and

$$\mathrm{Im}\, \phi_{ij} = \frac{M}{2\pi\, t_{ij}\, (f_b - f_a)} \left[\cos 2\pi\, t_{ij} f_a - \cos 2\pi\, t_{ij} f_b\right] \tag{3-10}$$

By employing the trigonometric identities

$$\sin a - \sin b = 2 \cos \left(\frac{a + b}{2}\right) \sin \left(\frac{a - b}{2}\right)$$

and

$$\cos b - \cos a = 2 \sin \left(\frac{a + b}{2}\right) \sin \left(\frac{a - b}{2}\right)$$

we can write Equations 3-9 and 3-10 as

$$\mathrm{Re}\ \overline{\phi}_{ij} = \frac{M}{\pi t_{ij} (f_b - f_a)} \left\{ \cos \left[\pi t_{ij} (f_a + f_b)\right] \sin \left[\pi t_{ij} (f_b - f_a)\right] \right\} \quad (3\text{-}11)$$

and

$$\mathrm{Im}\ \overline{\phi}_{ij} = - \frac{M}{\pi t_{ij} (f_b - f_a)} \left\{ \sin \left[\pi t_{ij} (f_b + f_a)\right] \sin \left[\pi t_{ij} (f_b - f_a)\right] \right\} \quad (3\text{-}12)$$

The magnitude of the crosspower estimate at frequency f_o is then

$$|\overline{\phi}_{ij}| = M \frac{\sin \pi t_{ij} (f_b - f_a)}{\pi t_{ij} (f_b - f_a)} \quad (3\text{-}13)$$

and the phase of the same function is

$$\arg \overline{\phi}_{ij} = \pi\ t_{ij} (f_b + f_a) \quad (3\text{-}14)$$

In general, the transform algorithms used in the estimation process have a constant-width smoothing function; i.e., $f_b - f_a = \Delta f$ = a constant. Thus, Equation 3-13 can be written

$$|\overline{\phi}_{ij}| = M \frac{\sin \pi\ t_{ij}\ \Delta f}{\pi\ t_{ij}\ \Delta f} \quad (3\text{-}15)$$

B. APPLICATION TO SEISMIC ARRAYS

The smoothing-moveout window functions are present in the frequency-domain processing of a seismic array when the auto-crosspower matrix is being estimated. Usually, the processed seismic data are broad-band, with the energy nearly uniformly distributed in a small band Δf; in this case, the crosspower phase estimated by Equation 3-14 will be a very good estimate of the actual phase, but the smoothing-moveout window function still will be present in the magnitude of the crosspower spectra estimated by Equation 3-15.

The effect of this window function is minimized when the product $t_{ij}\,\Delta f$ is minimized. To maintain all of the estimated auto- and crosspower spectra within 10 percent of each other, the function

$$\frac{\sin \pi t_m \Delta f}{\pi t_m \Delta f} \geq 0.9 \tag{3-16}$$

for the largest expected moveout t_m. This requires that

$$t_m \Delta f \leq \frac{1}{4} \tag{3-17}$$

These estimates are obtained from the transforms of data segments T-sec long. The smallest Δf obtainable with a segment of length T is approximately

$$\Delta f \cong \frac{1}{T} \tag{3-18}$$

This implies that

$$T \geq 4\, t_m$$

The length of the data segment transformed should be at least four times the largest expected moveout across the array.

In the single plane-wave case just considered, it appears that the window effect could be circumvented for $\Delta t < t_{ij} < \pi$ by normalizing the auto- and crosspower spectra; this would sacrifice information about the waveform amplitude for a better estimate of its crosspower. This normalizing can result in incorrect interpretation when two or more plane-wave signals of different velocities are present in the transform gate.

For two plane waves with moveouts t_1 and t_2, respectively, the crosspower at frequency f is

$$\phi(f) = M_1^2 \exp j\ 2\pi\ ft_1 + M_2^2 \exp j\ 2\pi\ ft_2 \tag{3-19}$$

$$+ M_1 M_2 \exp j\ 2\pi\ f\ (t_1 - t_2)$$

$$+ M_1 M_2 \exp j\ 2\pi\ f\ (t_2 - t_1)$$

where M_1 and M_2 are the respective amplitudes of the waves. The estimated crosspower can be expressed by integrating each term of Equation 3-19 over the interval f_a to f_b and operating on each term with the trigonometric identities in subsection A. The estimated crosspower for $\Delta f = f_b - f_a$ is then

$$\bar{\phi} = \left(\frac{\sin \pi t_1 \Delta f}{\pi t_1 \Delta f}\right) M_1^2 \exp j\pi t_1 (f_a + f_b) \tag{3-20}$$

$$+ \left(\frac{\sin \pi t_2 \Delta f}{\pi t_2 \Delta f}\right) M_2^2 \exp j\pi t_2 (f_a + f_b)$$

$$+ \left(\frac{\sin \pi (t_1 - t_2) \Delta f}{\pi (t_1 - t_2) \Delta f}\right) M_1 M_2 \exp \left\{\left[j\pi (t_1 - t_2)(f_a + f_b)\right]\right.$$

$$\left. + \exp\left[- j\pi (t_1 - t_2)(f_a + f_b)\right]\right\}$$

If the signals are wideband and the energy is uniformly distributed over the interval Δf, then $(f_a + f_b)$ is very close to $2f_o$ where f_o is the transform frequency point. The estimated crosspower then contains every term of the true crosspower, with each term multiplied by its own window function. By making Δf small, the window effects can be reduced and a reasonably good estimate obtained.

C. INCREASED GATE LENGTH'S EFFECTS ON CROSSPOWER ESTIMATES

Current applications of frequency-domain processing employ direct transforms of the time-domain data to estimate auto- and crosspower spectra. Since the transform algorithms (such as Cooley-Tukey) are finite and discrete, their outputs are functions of the energy rather than the power contained in the data segment transformed; this is especially true in seismic work where the signals being processed are transients.

Consider the transforms X_a and X_b of two data channels containing signal and additive noise. Then,

$$X_a = S_a + N_a$$

and

$$X_b = S_b + N_b$$

If the data segment is of length T, the computed transform points will have a frequency resolution limit (spectral window) of Δf_1 where

$$\Delta f_1 \approx \frac{1}{T}$$

The autopower spectrum of each channel is then estimated as the energy density spectrum

$$\bar{\phi}_a = X_a X_b^* = \left[S_a S_a^* + S_a N_a^* + N_a S_a^* + N_a N_a^*\right]$$

$$\bar{\phi}_b = X_b X_b^* = \left[S_b S_b^* + S_b N_b^* + N_b S_b^* + N_b N_b^*\right]$$

Similarly, the crosspower spectrum is estimated from the cross-energy density spectrum

$$\bar{\phi}_{ab} = X_a X_b^* = \left[S_a S_b^* + S_a N_b^* + N_a S_b^* + N_a N_b^*\right]$$

In these expressions,

$S_i S_i^*$ = signal energy in channel i

$N_i N_i^*$ = noise energy in channel i

$S_i S_j^*$ = signal energy common to i and j data channels

$N_i N_j^*$ = noise energy common to i and j data channels

For transient signals with an effective signal duration of $t_s < T$, the band Δf_s over which the signal energy is distributed in frequency is greater than $1/t_s$. A resolved band Δf_1 in the frequency range of the signal energy will contain some fraction of the total signal energy present in the data segment. If the data segment containing this signal is doubled in length (2T), the frequency resolution limit $\Delta f_2 = 0.5\ \Delta f_1$.

The total signal energy in the long segment is the same as the total signal energy in the short segment. A resolved band Δf_2 in the frequency range of the signal energy will then have half the average energy that a resolved band Δf_1 would have at the same frequency. Figure III-1 shows a typical signal energy spectrum.

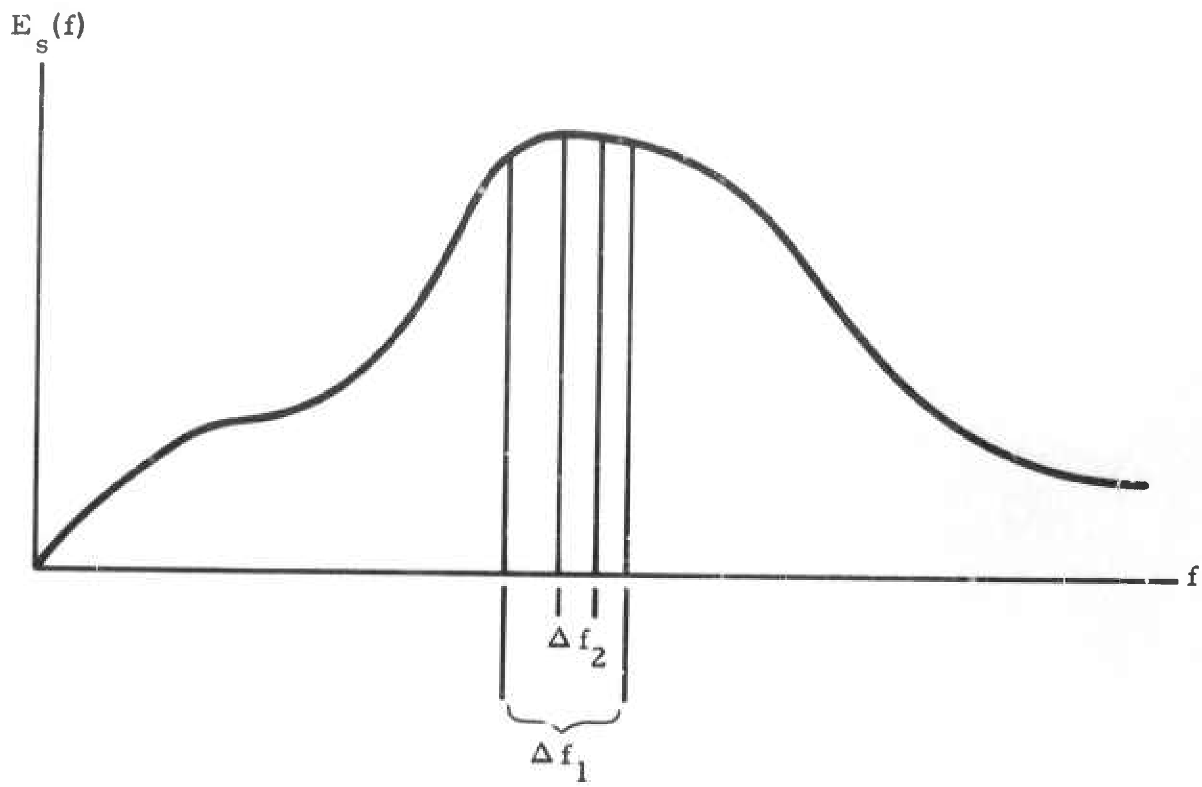

Figure III-1. Typical Signal Energy Spectrum

To be more precise, let $E_S(f)$ be the true energy density spectrum of the signal in the data segment. The signal energy in a resolved band is

$$E_S(\Delta f) = \int_{\Delta f} E_S(f)\, df$$

So, if

$$\Delta f_1 = 2\Delta f_2$$

then

$$E_S(\Delta f_1) \approx 2\, E_S(\Delta f_2)$$

Seismic noise is generally considered to be the output of a Gaussian process. Doubling the data gate length will then double the total noise energy in the data segment. The average noise energy in the resolved band Δf_2 using a double-length (2T) data segment will then be the same as the average noise energy in the resolved band Δf_1 of the single-length (T) data segment; i.e.,

$$E_N(\Delta f_1) \approx E_N(\Delta f_2)$$

If the applicable signal-to-noise ratio is considered to be the ratio of signal energy to noise energy in a data segment, doubling the data gate length reduces the signal-to-noise ratio by one-half:

$$\frac{E_S(\Delta f_2)}{E_N(\Delta f_2)} = \frac{1}{2}\left[\frac{E_S(\Delta f_1)}{E_N(\Delta f_1)}\right]$$

This is true whenever signal duration t_s is less than the data gate lengths being transformed.

D. LASA PROCESSING CONSIDERATIONS

Results of the previous analysis on the computation of high-resolution wavenumber spectra for the Montana LASA may be applied by considering the beamsteered improvement in signal-to-noise power. This approach is useful because the computation of standard wavenumber spectra is

the frequency-domain equivalent to time-shift-and-sum beam-forming followed by square-law detecting. In the frequency-domain processing considered, all time-domain data are transformed to the frequency domain before the performance of any beamsteering or other processing. The relative signal-to-noise gain for various LASA configurations will then give a general picture of the manner in which configuration and moveout constrain the processing.

To limit the extent of this comparison, the array configurations include all of the subarrays within and on the LASA ring under consideration. Thus, there are five array configurations for the B through the F rings. The signals of interest have greater than 10-km/sec apparent velocity across the array, so the maximum expected moveout for each configuration is

$$t_{m_j} = \frac{d_j}{10 \text{ km/sec}}$$

where d_j is the diameter of the j^{th} ring.

If the array is enlarged by adding all of the subarrays on the next ring out, the transform gate length T_j must be increased to maintain the same spectral window; this increases the transform gate length to

$$T_{j+1} = \left(\frac{t_{m,\,j+1}}{t_{m,\,j}}\right) T_j = \left(\frac{d_{j+1}}{d_j}\right) T_j$$

The loss in effective signal-to-noise ratio due to the increase in gate length is then

$$L_{j+1} = \frac{T_j}{T_{j+1}} = \frac{d_j}{d_{j+1}}$$

As the array is expanded, more sensors are added. Assuming that the seismic noise field is uncorrelated from subarray to subarray, the beamsteered signal-to-noise power gain of the j^{th} array over a single subarray is

$$G_j = N_j = \text{number of subarrays in } j^{th} \text{ configuration}$$

The total gain (or loss) obtained by adding one ring to the j^{th} array configuration is then

$$H_{j+1,j} = L_{j+1} \left(\frac{G_{j+1}}{G_j}\right) = \left(\frac{d_j}{d_{j+1}}\right)\left(\frac{N_{j+1}}{N_j}\right)$$

As successively larger rings are added to the beamsteering process, the signal-to-noise improvement predicted for LASA increases with the increase in the number of subarrays and decreases with the increase in aperture. This function is plotted in Figure III-2.

This analysis indicates a serious drawback in using rings outside the C ring for frequency-domain signal processing. To include the D ring reduces the beamsteer gain 20 percent, while the E and F rings reduce the beamsteer gain 50 and 60 percent, respectively. These decreases result from doubling the array aperture while not doubling the number of subarrays.

In the light of this analysis, the use of subarrays on the E and F rings when computing high-resolution wavenumber spectra for LASA does not appear advantageous.

Ring	Diameter (km)	No. of Sensors	Gain Over Last Ring
B	18	4	5
C	31	4	1.05
D	58	4	0.77
E	120	4	0.64
F	200	4	0.74

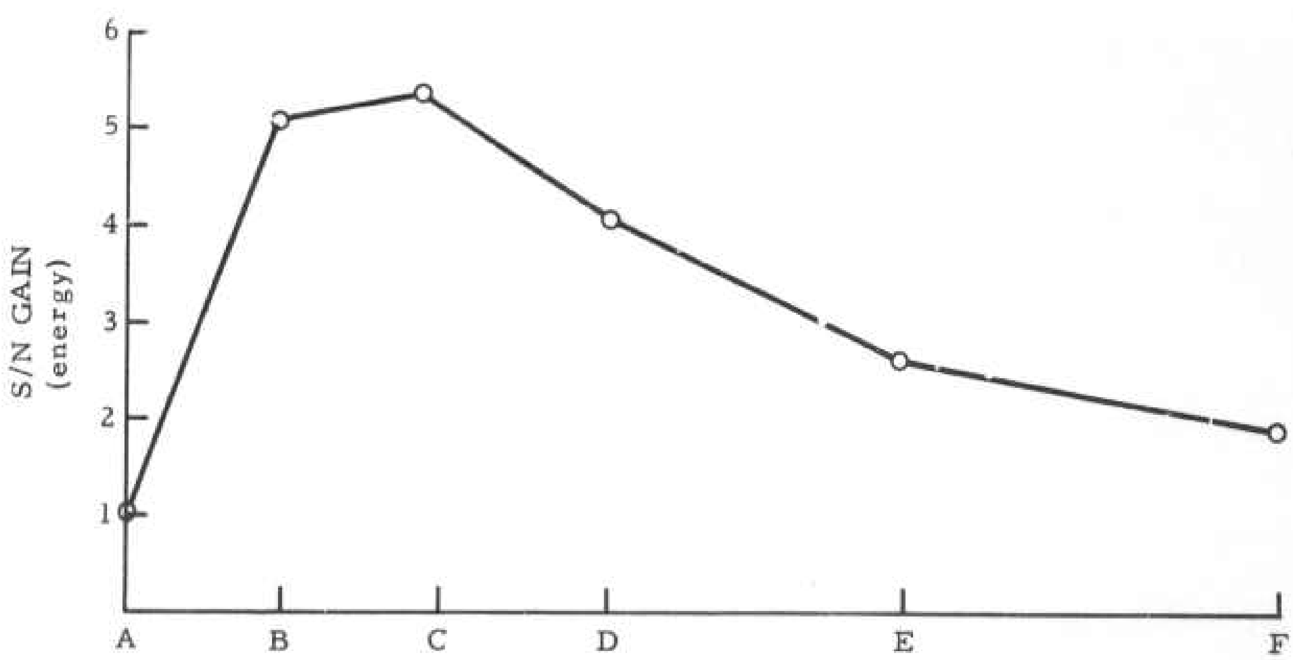

Figure III-2. Signal-to-Noise Improvement

SECTION IV
CONCLUSIONS

From this study, there are two major conclusions:

- Current data are insufficient to define a scheme adequately to correct wavenumber spectra calculations for traveltime anomalies
- Subarrays on the E and F rings of LASA will not be included in high-resolution f-$\vec{k}$ spectra calculations

Subarrays on the E and F rings of LASA generally exhibit larger traveltime residuals and less waveform similarity than do subarrays of the inner rings.* Current data appear to be inadequate to describe these anomalies with any degree of certainty. With this lack of knowledge of the anomaly mechanism, coupled with the spectral window considerations, the use of subarrays on the E and F rings of LASA is unadvisable.

*Texas Instruments Incorporated, 1967: Short-Period Signal Waveform at LASA, Large-Array Signal and Noise Analysis, Spec. Rpt. No. 8, Contract AF 33(657)-16678, 1 Aug.

APPENDIX A

TRAVELTIME RESIDUALS

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BLOCK NO = (11.12) NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	0.1125	
B2	0.0011	
B3	0.0000	
B4	-0.0265	
C1	0.0566	
C2	0.0471	
C3	-0.0241	
C4	-0.0874	
D1	0.1241	
D2	-0.0962	
D3	-0.1890	
D4	0.0072	
E1	-0.0294	
E2	-0.0149	
E3	0.0000	
E4	-0.1890	
F1	0.0534	
F2	-0.2309	
F3	-0.1145	
F4	0.0000	

BLOCK NO = (11.14) NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0512	
B2	0.0314	
B3	-0.0551	
B4	-0.0662	
C1	-0.0129	
C2	-0.0125	
C3	-0.0029	
C4	-0.0449	
D1	-0.0016	
D2	-0.2048	
D3	-0.1122	
D4	-0.0461	
E1	-0.1185	
E2	-0.0375	
E3	-0.2282	
E4	-0.1633	
F1	0.1013	
F2	-0.3262	
F3	-0.1322	
F4	-0.2651	

BLOCK NO = (12.11)   NO OF EVENTS = 5

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0267	0.0000
B2	0.0700	0.0000
B3	-0.0682	0.0941
B4	0.0272	0.0398
C1	-0.0388	0.0000
C2	0.0747	0.0906
C3	-0.0660	0.0955
C4	-0.0041	0.0139
D1	0.0463	0.0472
D2	-0.0468	0.0731
D3	-0.0946	0.0953
D4	0.0835	0.0866
E1	-0.1778	0.1890
E2	-0.1321	0.1321
E3	-0.1701	0.0868
E4	-0.0893	0.0483
F1	-0.0276	0.0603
F2	-0.2429	0.0917
F3	-0.1091	0.0730
F4	-0.0355	0.0406

BLOCK NO = (12.12)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0499	
B2	0.0529	
B3	-0.0631	
B4	-0.0329	
C1	0.0180	
C2	0.0595	
C3	-0.0589	
C4	-0.0787	
D1	0.0872	
D2	0.0000	
D3	-0.1907	
D4	0.0000	
E1	-0.2080	
E2	0.0967	
E3	-0.1783	
E4	-0.1766	
F1	-0.0376	
F2	-0.3228	
F3	-0.1791	
F4	[illegible]	

4

5

BLOCK NO = (13,10)   NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0606	0.0356
B2	0.0457	0.0017
B3	-0.0358	0.0573
B4	0.0235	0.0011
C1	0.0841	0.0882
C2	0.0012	0.0522
C3	-0.0283	0.0178
C4	-0.0183	0.1294
D1	0.1398	0.0603
D2	-0.0270	0.0253
D3	-0.1459	0.0398
D4	0.0333	0.0550
E1	-0.0532	0.0288
E2	-0.0375	0.0079
E3	-0.2435	0.0011
E4	-0.1788	0.0984
F1	-0.0767	0.1714
F2	-0.4108	0.0501
F3	-0.1000	0.1129
F4	0.0049	0.1340

BLOCK NO = (13,11)   NO OF EVENTS = 4

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0987	0.0718
B2	0.0473	0.0584
B3	-0.1413	0.2051
B4	0.0374	0.0305
C1	0.0698	0.0516
C2	0.1104	0.0917
C3	-0.0329	0.0704
C4	-0.0545	0.0162
D1	0.1308	0.0369
D2	-0.0634	0.0845
D3	-0.1000	0.1217
D4	0.0605	0.0378
E1	0.0000	-0.0000
E2	0.0350	0.0000
E3	-0.0132	0.0000
E4	-0.2421	0.2035
F1	-0.0163	0.0627
F2	-0.3430	0.2841
F3	-0.0894	0.0000
F4	-0.1249	0.2130

[illegible]

SUBARRAY	MEAN	STD.DEVIATION
[illegible]	0.0962	[illegible]
[illegible]	0.0679	[illegible]
B3	-0.0440	0.0300
B4	-0.0080	0.0000
[illegible]	[illegible]	0.1805
[illegible]	[illegible]	0.0974
C3	0.0296	0.0730
C4	-0.0217	0.0221
[illegible]	0.2352	[illegible]
[illegible]	-0.0772	0.0839
D3	-0.0581	0.0349
D4	0.0326	0.0359
E1	0.0497	[illegible]
E2	0.0285	0.0692
E3	-0.1292	0.1618
E4	-0.1966	0.1146
F1	0.0881	[illegible]
F2	-0.1898	[illegible]
F3	0.2248	0.0641
F4	-0.0508	0.0271

2

2

3

BLOCK NO = (15, 9)   NO OF EVENTS = 6

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0105	[illegible]
B2	0.0144	0.0854
B3	-0.0712	0.0485
B4	-0.0684	[illegible]
C1	0.0339	[illegible]
C2	0.0382	0.0779
C3	-0.0480	0.0563
C4	[illegible]	0.0682
D1	0.1081	0.0898
D2	0.0217	0.0271
D3	-0.0496	0.0554
D4	[illegible]	[illegible]
E1	[illegible]	0.0707
E2	0.0541	0.1091
E3	-0.2112	0.0826
E4	[illegible]	[illegible]
F1	0.0410	0.0961
F2	-0.3613	0.0422
F3	-0.0647	0.1439

2

BLOCK NO = (15,10)   NO OF EVENTS = [illegible]

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0603	0.0000
B2	0.1058	0.0000
B3	-0.0017	0.0000
B4	0.0006	0.0272
C1	0.1537	0.1587
C2	0.1602	0.1692
C3	0.0054	0.0000
C4	-0.0569	0.0534
D1	0.1831	0.0405
D2	0.0337	0.1474
D3	0.0116	0.0154
D4	-0.0010	0.0617
E1	-0.0024	0.0584
E2	0.1184	0.0000
E3	0.0000	-0.0000
E4	-0.2190	0.2370
F1	0.1543	0.1545
F2	-0.1759	0.0000
F3	0.1386	0.1650
F4	-0.0589	0.0594

BLOCK NO = (16, 9)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0980	
B2	-0.0727	
B3	-0.1312	
B4	0.0133	
C1	-0.1438	
C2	-0.0217	
C3	0.0000	
C4	0.0449	
D1	-0.0256	
D2	-0.0626	
D3	0.0143	
D4	-0.0964	
E1	-0.0462	
E2	0.0260	
E3	-0.2531	
E4	-0.1743	
F1	-0.0545	
F2	-0.4144	
F3	0.0350	
F4	-0.2811	

3

BLOCK NO = (16,13)   NO OF EVENTS = 4

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0984	0.1083
B2	0.0764	0.0462
B3	0.0150	0.0323
B4	-0.0358	0.0329
C1	-0.0333	0.0214
C2	-0.1111	0.1547
C3	0.0698	0.0325
C4	-0.0348	0.0411
D1	-0.1988	0.0451
D2	-0.1519	0.0788
D3	-0.1239	0.0718
D4	-0.0017	0.0500
E1	-0.1852	0.1597
E2	-0.1374	0.0756
E3	-0.2554	0.0381
E4	-0.0237	0.0544
F1	0.0000	-0.0000
F2	-0.4501	0.0684
F3	-0.1066	0.0684
F4	-0.2504	0.1267

3

3

II

BLOCK NO = (16,3[illegible])   NO OF EVENTS = 4

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0565	0.0520
B2	-0.1850	0.2620
B3	-0.0367	0.0610
B4	0.0166	0.0497
C1	-0.0534	[illegible]
C2	-0.1448	0.2077
C3	-0.3952	0.0000
C4	0.0091	0.0858
D1	-0.1209	[illegible]
D2	-0.4973	0.7034
D3	-0.1799	0.1296
D4	-0.0[illegible]	[illegible]
E1	0.0171	0.0436
E2	-0.0901	0.0458
E3	-0.4828	0.3427
E4	-0.4575	0.0000
F1	0.3189	0.4509
F2	-0.5657	0.1001
F3	-0.8162	0.0000
F4	-0.3503	[illegible]

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BLOCK NO = (17, 9)   NO OF EVENTS = 7

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0686	0.1417 —
B2	0.0781	0.0758
B3	-0.0500	0.0535
B4	-0.0359	0.0380
C1	0.0590	0.0770
C2	0.1214	0.0923
C3	0.0023	0.0323
C4	-0.0392	0.0592
D1	0.2519	0.1590 —
D2	-0.0752	0.1029 -
D3	-0.0252	0.0658
D4	0.0126	0.0381
E1	0.0585	0.0684
E2	0.1539	0.1070 —
E3	-0.2297	0.1116 -
E4	-0.1423	0.0654
F1	0.1041	0.0535
F2	-0.4444	0.2008 —
F3	-0.2212	0.0445
F4	-0.1898	0.0617

BLOCK NO = (17, 11)   NO OF EVENTS = 4

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0247	0.0976
B2	0.0485	0.0000
B3	-0.1238	0.1751 —
B4	-0.0371	0.0813
C1	0.0136	0.0946
C2	0.0019	0.0246
C3	-0.0582	0.0776
C4	-0.0609	0.0930
D1	-0.0736	0.0699
D2	-0.0983	0.1032 —
D3	-0.1525	0.1139 —
D4	-0.0224	0.0771
E1	-0.1731	0.0486
E2	-0.0742	0.0284
E3	-0.3934	0.1161 —
E4	-0.1432	0.0618
F1	-0.2502	0.3544 —
F2	-0.5291	0.0509
F3	-0.3493	0.0852
F4	0.3023	0.0471

BLOCK NO = (17.12)   NO OF EVENTS = 12

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0297	0.0412
B2	0.0204	0.0782
B3	-0.0667	0.0747
B4	-0.0439	0.0607
C1	0.0454	0.0809
C2	-0.0366	0.0574
C3	-0.0247	0.0431
C4	-0.0795	0.0514
D1	-0.0881	0.0528
D2	-0.1187	0.0808
D3	-0.1533	0.1075
D4	-0.0184	0.0593
E1	-0.1304	0.0467
E2	-0.0609	0.0742
E3	-0.3840	0.2944
E4	-0.1361	0.0640
F1	-0.2975	[illegible]
F2	-0.5266	0.1810
F3	-0.3173	0.2944
F4	-0.3096	0.1198

BLOCK NO = (17.13)   NO OF EVENTS = 4

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0883	0.0789
B2	0.1020	0.1473
B3	0.0306	0.0543
B4	-0.0441	0.0191
C1	-0.0211	0.0278
C2	-0.0647	0.0491
C3	0.0708	0.0364
C4	-0.0067	0.0358
D1	-0.2199	0.1742
D2	-0.1693	0.0276
D3	-0.0811	0.0377
D4	0.0874	0.0905
E1	-0.2018	0.0116
E2	-0.0651	0.1178
E3	-0.2892	0.0443
E4	-0.0185	0.0418
F1	-0.2740	0.0000
F2	-0.4059	0.0280
F3	-0.1167	0.0468
F4	-0.2890	0.2044

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BLOCK NO = (17.14)   NO OF EVENTS = 6

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0972	0.2064
B2	0.0238	0.0639
B3	0.0088	0.0283
B4	-0.0436	0.0648
C1	-0.0293	0.0499
C2	-0.0279	0.0386
C3	0.0424	0.0529
C4	0.0037	0.0310
D1	-0.2146	0.1791
D2	-0.1887	0.0993
D3	-0.0956	0.0540
D4	0.0553	0.0353
E1	-0.2720	0.0341
E2	-0.1169	0.0799
E3	-0.2719	0.2299
E4	0.0193	0.0865
F1	-0.2902	0.2399
F2	-0.4564	0.3946
F3	-0.1826	0.0967
F4	-0.2520	0.0775

BLOCK NO = (17.15)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0000	
B2	0.0000	
B3	0.0000	
B4	0.0000	
C1	-0.0867	
C2	-0.0881	
C3	0.0794	
C4	-0.0123	
D1	-0.2192	
D2	0.0000	
D3	-0.0937	
D4	0.0555	
E1	-0.1703	
E2	-0.1722	
E3	-0.3288	
E4	0.0000	
F1	-0.2735	
F2	-0.4484	
F3	-0.2457	
F4	-0.0429	

BLOCK NO = (17,23)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0000	
B2	0.0000	
B3	0.0000	
B4	0.0000	
C1	0.0786	
C2	0.0095	
C3	-0.0050	
C4	-0.0917	
D1	0.0000	
D2	-0.1782	
D3	-0.3060	
D4	-0.0299	
E1	0.1566	
E2	-0.0916	
E3	-0.5244	
E4	-0.5295	
F1	0.1769	
F2	-0.4795	
F3	-0.6302	
F4	-0.4951	

BLOCK NO = (17,29)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0081	
B2	-0.1384	
B3	-0.0071	
B4	-0.0346	
C1	-0.1731	
C2	-0.2545	
C3	-0.2490	
C4	-0.0305	
D1	-0.0356	
D2	-0.4087	
D3	-0.0854	
D4	[illegible]	
E1	0.0000	
E2	-0.4344	
E3	-0.3756	
E4	-0.3932	
F1	-0.3879	
F2	-0.8711	
F3	-0.7343	
F4	-0.8920	

BLOCK NO = (17,38)   NO OF EVENTS =   1

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0389	
B2	-0.2856	
B3	-0.0495	
B4	0.0481	
C1	-0.0849	
C2	-0.1847	
C3	-0.4379	
C4	0.0127	
D1	-0.1235	
D2	-0.5048	
D3	-0.1900	
D4	-0.0454	
E1	0.0321	
E2	-0.1003	
E3	-0.4625	
E4	-0.3900	
F1	0.3081	
F2	-0.5891	
F3	-0.9093	
F4	-0.3170	

BLOCK NO = (18, 9)   NO OF EVENTS =   6

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0108	0.0575
B2	0.0767	0.0836
B3	-0.0395	0.0411
B4	-0.0668	0.0485
C1	0.0531	0.0563
C2	0.0559	0.0733
C3	-0.0021	0.0401
C4	-0.0681	0.0317
D1	0.1570	[illegible]
D2	-0.0827	0.1258
D3	-0.0414	0.0733
D4	-0.0197	0.0527
E1	0.0924	0.0532
E2	0.0396	0.0715
E3	-0.2291	0.0830
E4	-0.0456	0.0577
F1	-0.0128	0.0591
F2	-0.5861	0.3033
F3	-0.1737	0.0856
F4	-0.1290	0.0132

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[illegible]

SUBARRAY	MEAN	STD.DEVIATION
B1	[illegible]	[illegible]
B2	[illegible]	[illegible]
B3	-0.0586	0.0700
B4	-0.0489	0.0559
C1	[illegible]	[illegible]
C2	[illegible]	[illegible]
C3	-0.0237	0.0752
C4	-0.0609	0.0679
D1	0.1044	[illegible]
D2	-0.1518	[illegible]
D3	-0.0717	0.0584
D4	-0.0133	0.0548
E1	0.0280	[illegible]
E2	-0.0297	[illegible]
E3	-0.3405	0.0974
E4	-0.1235	[illegible]
F1	[illegible]	[illegible]
F2	-0.6222	[illegible]
F3	-0.2431	0.0851
F4	-0.1887	0.1129

BLOCK NO = (18.11)   NO OF EVENTS = 7

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0683	[illegible]
B2	0.0590	0.0724
B3	-0.0498	0.0799
B4	-0.0501	[illegible]
C1	0.0872	[illegible]
C2	0.0403	0.0422
C3	-0.0458	0.0374
C4	[illegible]	[illegible]
D1	[illegible]	[illegible]
D2	-0.1099	0.0785
D3	-0.0923	0.0457
D4	[illegible]	[illegible]
E1	[illegible]	[illegible]
E2	-0.0781	0.0797
E3	-0.3869	0.0627
E4	[illegible]	[illegible]
F1	-0.2886	[illegible]
F2	-0.5753	0.0668
F3	-0.3034	0.0672
F4	[illegible]	[illegible]

BLOCK NO = (18.13)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.1733	
B2	0.0273	
B3	-0.0841	
B4	-0.1241	
C1	0.0930	
C2	0.0000	
C3	-0.0330	
C4	-0.0206	
D1	-0.1929	
D2	-0.2329	
D3	-0.0751	
D4	0.0000	
E1	-0.3194	
E2	-0.1212	
E3	0.0000	
E4	-0.0035	
F1	0.0000	
F2	-0.5911	
F3	-0.2079	
F4	-0.3055	

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2

3

BLOCK NO = (18.14)   NO OF EVENTS = 8

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.1296	0.[illegible]402
B2	0.0400	0.0660
B3	0.0077	0.0586
B4	-0.0011	0.0657
C1	-0.0154	0.0867
C2	-0.0254	0.0634
C3	0.0576	0.0611
C4	0.0166	0.0764
D1	-0.1820	0.1218
D2	-0.2169	0.1953
D3	-0.0963	0.0676
D4	0.0999	0.0729
E1	-0.2509	0.12[illegible]
E2	-0.0480	0.0634
E3	-0.3139	0.2020
E4	0.0638	0.[illegible]65
F1	-0.2288	0.2020
F2	-0.4056	0.1899
F3	-0.2196	0.0742
F4	-0.2254	0.0642

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BLOCK NO = (18,15)   NO OF EVENTS = 4

SUBARRAY	MEAN	STD.DEVIATION	
B1	-0.1049	0.0811	
B2	-0.0170	0.0626	
B3	0.0041	0.0312	
B4	-0.0619	0.10[illegible]	
C1	-0.0899	0.1061	
C2	-0.0864	0.1282	6
C3	0.0398	0.0666	
C4	0.0074	0.0315	
D1	-0.1507	0.1215	
D2	-0.2196	0.1607	
D3	-0.0990	0.0389	
D4	0.0210	0.0408	
E1	-0.1897	0.0822	
E2	0.0293	0.0366	3
F3	-0.3177	0.2281	
F4	0.1012	0.0460	
F1	-0.2110	0.149[illegible]	
F2	-0.4194	0.3038	4
F3	-0.1367	0.1147	
F4	-0.1901	0.1131	

BLOCK NO = (18,16)   NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION	
B1	-0.0010	0.0000	
B2	0.0186	0.1131	
B3	-0.0021	0.0000	
B4	-0.0920	0.0068	
C1	-0.0943	[illegible]	6
C2	-0.0623	0.0000	
C3	0.0844	0.0135	
C4	-0.0593	0.0280	
D1	-0.0406	0.0726	
D2	-0.0962	0.0000	
D3	-0.1630	0.0338	
D4	-0.1011	0.0572	
E1	-0.3855	0.0295	
F2	0.3392	0.0000	
F3	-0.1047	0.0537	
F4	-0.1456	0.0283	
F1	-0.1151	0.0356	
F2	-0.0083	0.0416	
F3	-0.0688	0.0062	
F4	-0.3524	[illegible]	

BLOCK NO = (18,25)   NO OF EVENTS = 7

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0129	0.0570
B2	-0.0518	0.0765
B3	-0.0233	0.0415
B4	-0.0352	0.0820
C1	0.0284	0.0504
C2	-0.0274	0.0476
C3	-0.1545	0.1238
C4	-0.1982	0.1495
D1	0.0330	0.0647
D2	-0.2963	0.2373
D3	-0.2790	0.1778
D4	-0.1311	0.1014
E1	0.1096	0.0580
E2	-0.2813	0.0664
E3	-0.5937	0.2861
E4	-0.7161	0.3295
F1	0.0948	0.0429
F2	-0.6754	0.0461
F3	-0.9231	0.0678
F4	-0.4722	0.0819

BLOCK NO = (18,22)   NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0156	0.0041
B2	-0.1491	0.0017
B3	0.0155	0.0145
B4	0.0452	0.0335
C1	-0.1304	0.0054
C2	-0.1693	0.0060
C3	-0.1756	0.0090
C4	-0.0291	0.0576
D1	-0.0741	0.0069
D2	-0.4135	0.0000
D3	-0.1984	0.0650
D4	-0.0538	0.0214
E1	-0.1138	0.0616
E2	-0.4115	0.0568
E3	-0.5878	0.0632
E4	-0.5369	0.1158
F1	-0.3325	0.0531
F2	-0.8623	0.0000
F3	-0.8522	0.0280
F4	-0.5406	0.0036

BLOCK NO = (19.29) NO OF [illegible]

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0668	0.0175
B2	-0.1232	0.0461
B3	0.0592	0.0293
B4	-0.0064	0.0349
C1	-0.0379	0.0341
C2	-0.2036	0.0317
C3	-0.1980	0.0536
C4	-0.0214	0.0211
D1	-0.1510	[illegible]
D2	-0.4556	0.0364
D3	-0.1194	0.0341
D4	-0.0911	0.0579
E1	-0.1593	[illegible]
E2	-0.4877	0.0290
F3	-0.4940	0.2874
F4	-0.4149	0.0339
F1	-0.3019	[illegible]
F2	-0.8694	[illegible]
F3	-0.7497	0.0454
F4	-0.5485	0.3177

BLOCK NO = (18.32) NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.1303	[illegible]
B2	-0.2975	0.0498
B3	0.0166	0.0496
B4	0.0345	[illegible]
C1	-0.1078	[illegible]
C2	-0.3319	0.1420
C3	-0.3336	0.0351
C4	[illegible]	[illegible]
D1	-0.2301	[illegible]
D2	-0.6504	0.0061
D3	-0.0730	0.0002
D4	[illegible]	[illegible]
E1	[illegible]	[illegible]
F2	-0.5870	0.0000
F3	-0.6179	0.0202
F4	[illegible]	[illegible]
F1	-0.2969	[illegible]
F2	-0.7813	0.0109
F3	-0.5741	0.0022
F4	[illegible]	[illegible]

BLOCK NO = (19.[illegible]) NO OF EVENTS = [illegible]

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0000	
B2	0.0000	
B3	0.0000	
B4	0.0154	
C1	0.1094	
C2	0.1880	
C3	0.0288	
C4	-0.0413	
D1	0.2149	
D2	-0.0260	
D3	-0.0113	
D4	0.0317	
E1	0.0733	
E2	0.0010	
E3	0.0000	
E4	-0.0522	
F1	0.0000	
F2	-0.5358	
F3	0.0000	
F4	-0.0227	

BLOCK NO = (19.14) NO OF EVENTS = 5

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.1263	0.0000
B2	0.0242	0.0000
B3	-0.0035	0.0000
B4	-0.0754	0.1102
C1	-0.0260	0.0882
C2	-0.0889	0.0604
C3	0.0577	0.0674
C4	-0.0206	0.0361
D1	-0.1614	0.1054
D2	-0.2083	0.3680
D3	-0.0352	0.0730
D4	0.0913	0.0309
E1	-0.2062	0.1817
E2	-0.0523	0.0571
E3	-0.3835	0.6662
E4	0.0610	[illegible]
F1	-0.2672	0.1579
F2	-0.4211	0.0313
F3	-0.3122	0.0423
F4	-0.2512	0.0672

BLOCK NO = [illegible] NO OF [illegible]

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.1264	0.0279
B2	-0.0074	0.0591
B3	-0.0155	0.0468
B4	-0.0803	0.0724
C1	-0.1285	0.0328
C2	-0.1196	0.0831
C3	-0.0155	0.0594
C4	-0.0421	0.0341
D1	-0.1732	0.0286
D2	-0.1991	0.1738
D3	-0.1330	0.0299
D4	0.0856	0.0440
E1	-0.2222	0.0477
E2	0.0346	0.1923
E3	-0.3775	0.1768
E4	0.1161	0.0813
F1	-0.1855	[illegible]
F2	-0.2574	[illegible]
F3	-0.2303	0.0443
F4	-0.1422	0.1881

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BLOCK NO = (19.30) NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0066	
B2	-0.1710	
B3	0.1029	
B4	0.1042	
C1	0.0276	
C2	-0.1842	
C3	-0.2615	
C4	0.1399	
D1	-0.0780	
D2	-0.4827	
D3	-0.0906	
[illegible]	[illegible]	
E1	[illegible]	
E2	-0.5507	
E3	-0.6100	
[illegible]	[illegible]	
F1	-0.2987	
F2	-0.8940	
F3	-0.8066	
[illegible]	[illegible]	

8

4

BLOCK NO = (19.31) NO OF EVENTS = 8

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0869	0.0768
B2	-0.2714	0.1723
B3	0.0487	0.0334
B4	0.0711	0.0437
C1	-0.0304	0.0444
C2	-0.3336	0.2129
C3	-0.2962	0.2124
C4	0.1193	0.0670
D1	-0.1756	0.1055
D2	-0.5605	0.6486
D3	-0.1093	0.0714
D4	-0.0428	0.0520
E1	-0.1831	0.0987
E2	-0.4933	0.2152
E3	-0.5477	0.2300
E4	-0.2547	0.1124
F1	-0.3022	0.0361
F2	-0.7709	0.4979
F3	-0.5879	0.2533
F4	-0.4306	0.0406

BLOCK NO = (19.32) NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.1161	0.0424
B2	-0.2363	0.0424
B3	0.0331	0.0424
B4	0.0567	0.0636
C1	-0.0113	0.0000
C2	-0.3425	0.0000
C3	-0.3364	0.0000
C4	0.1146	0.0636
D1	-0.1892	0.0141
D2	-0.5744	0.0000
D3	-0.1351	0.0636
D4	0.0949	0.0000
E1	-0.1330	0.0000
E2	-0.5195	0.0354
E3	0.0000	-0.0000
E4	-0.1877	0.0000
F1	-0.1557	0.0000
F2	-0.8058	0.0000
F3	-0.4723	0.0495
F4	-0.4152	0.0495

BLOCK NO = (20,15)   NO OF EVENTS = 9

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.1054	0.0696
B2	-0.0082	0.0669
B3	-0.0590	0.0422
B4	-0.1263	0.0878
C1	-0.1085	0.0635
C2	-0.0664	0.0700
C3	-0.0633	0.0199
C4	-0.1099	0.1226
D1	-0.0693	0.0886
D2	-0.2260	0.1407
D3	-0.1537	0.0719
D4	0.0348	0.0473
E1	-0.1540	0.0841
E2	0.0171	0.0337
E3	-0.3764	0.0449
E4	-0.0351	0.0480
F1	0.0017	0.1015
F2	-0.3735	0.2228
F3	-0.2716	0.0579
F4	-0.3333	0.0951

II

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BLOCK NO = (20,16)   NO OF EVENTS = 3

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.1407	0.0409
B2	-0.0336	0.0389
B3	-0.0534	0.0488
B4	-0.1199	0.0250
C1	-0.1397	[illegible]
C2	-0.1188	0.1191
C3	-0.0751	0.0251
C4	-0.1160	0.0086
D1	-0.1604	0.0279
D2	-0.2446	0.0347
D3	-0.2180	0.2201
D4	0.0078	0.0378
E1	-0.2153	0.0368
E2	-0.0307	0.0380
E3	-0.3397	0.0159
E4	-0.0379	0.0378
F1	-0.0685	0.0486
F2	-0.2973	0.1349
F3	-0.2535	0.0212
F4	-0.3844	[illegible]

BLOCK NO = (20.31)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.1079	
B2	-0.2876	
B3	0.0000	
B4	-0.0058	
C1	-0.0908	
C2	-0.3380	
C3	-0.2349	
C4	0.0121	
D1	-0.2482	
D2	-0.5155	
D3	0.0000	
D4	-0.0432	
E1	-0.2565	
E2	-0.5506	
E3	-0.7097	
E4	-0.4137	
F1	-0.3413	
F2	-0.8242	
F3	-0.6222	
F4	-0.4597	

BLOCK NO = (21.16)   NO OF EVENTS = 7

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0713	0.0694
B2	-0.0166	0.0657
B3	0.0132	0.0552
B4	-0.0799	0.0896
C1	-0.0894	0.0905
C2	-0.0014	0.0502
C3	-0.0527	0.0209
C4	-0.1384	0.1503
D1	-0.0447	0.0545
D2	-0.1984	0.0743
D3	-0.1537	0.0756
D4	-0.0026	0.0517
E1	-0.1006	0.0561
E2	-0.0477	0.0406
E3	-0.2957	0.3005
E4	-0.1044	0.0919
F1	-0.0094	0.0463
F2	-0.3430	0.2491
F3	-0.3669	0.0434
F4	-0.3410	0.1652

BLOCK NO = (21,17) NO OF EVENTS = 3

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.1062	0.0158
B2	-0.0363	0.0360
B3	-0.0325	0.0193
B4	-0.1620	0.0673
C1	-0.0847	0.1021
C2	-0.0228	0.0346
C3	-0.0903	0.0182
C4	-0.1503	0.0086
D1	0.0098	0.0297
D2	-0.1401	0.1460
D3	-0.2137	0.0455
D4	-0.1357	0.0562
E1	-0.1621	0.0427
E2	-0.1016	0.0474
E3	-0.3716	0.0424
E4	-0.2099	0.0100
F1	0.1074	0.0567
F2	-0.3678	0.0201
F3	-0.4086	0.0114
F4	-0.4904	0.0499

BLOCK NO = (21,18) NO OF EVENTS = 5

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0580	0.1051
B2	-0.0610	0.0573
B3	-0.0372	0.0754
B4	-0.1810	0.1100
C1	-0.1153	0.0964
C2	-0.0711	0.1387
C3	-0.0667	0.0858
C4	-0.1580	0.1060
D1	-0.0506	0.0234
D2	-0.1420	0.1329
D3	-0.2221	0.1370
D4	-0.1249	0.1374
E1	-0.1215	0.0839
E2	-0.0415	0.0654
E3	-0.2987	0.0479
E4	-0.1482	0.1266
F1	0.1309	0.0921
F2	-0.2823	0.1849
F3	-0.3731	0.0427
F4	-0.4552	0.2690

BLOCK NO = (22.16)   NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.1513	0.0887
B2	-0.0679	0.0566
B3	-0.0520	0.0650
B4	0.0000	-0.0000
C1	-0.1320	0.0000
C2	-0.1148	0.0282
C3	-0.0735	0.0492
C4	-0.1588	0.0000
D1	-0.0811	0.0000
D2	0.0000	-0.0000
D3	-0.1347	0.0852
D4	-0.0319	0.0000
E1	-0.0651	0.0000
E2	-0.0939	0.1118
E3	-0.2583	0.0000
E4	-0.1139	0.0000
F1	0.0260	0.0952
F2	-0.4263	0.1164
F3	-0.4440	0.0141
F4	-0.3146	0.0230

BLOCK NO = (22.17)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0000	
B2	-0.0451	
B3	-0.0513	
B4	-0.0844	
C1	-0.1700	
C2	-0.0656	
C3	-0.0521	
C4	-0.1723	
D1	-0.0793	
D2	-0.1337	
D3	-0.2800	
D4	-0.1187	
E1	-0.1064	
E2	-0.0586	
E3	-0.3613	
E4	-0.2570	
F1	0.1152	
F2	-0.2908	
F3	-0.4423	
F4	-0.3908	

BLOCK NO = (22,38)   NO OF EVENTS = [illegible]

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0000	
B2	-0.2183	
B3	-0.1194	
B4	0.0000	
C1	0.0000	
C2	-0.1216	
C3	-0.3567	
C4	0.1467	
D1	0.0000	
D2	-0.4021	
D3	0.0000	
D4	0.0000	
F1	0.1354	
E2	-0.2941	
F3	-0.5145	
F4	0.0000	
F1	0.0000	
F2	-0.8778	
F3	0.0000	
F4	0.0000	

BLOCK NO = (23, 5)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0000	
B2	0.0000	
B3	0.0000	
B4	0.0000	
C1	0.0000	
C2	-0.3076	
C3	0.0000	
C4	0.0000	
D1	0.0000	
D2	0.0000	
D3	0.5873	
D4	-0.293[illegible]	
E1	0.0000	
F2	0.0000	
F3	-0.1781	
F4	0.490[illegible]	
F1	0.0000	
F2	0.0000	
F3	0.0681	
F4	0.0698	

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BLOCK NO = (23.15)   NO OF EVENTS =   1

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0000	
B2	0.0000	
B3	0.0000	
B4	0.0000	
C1	0.0000	
C2	0.0000	
C3	-0.0924	
C4	-0.1435	
D1	-0.1290	
D2	-0.3527	
D3	-0.2716	
D4	-0.1943	
E1	0.0000	
E2	0.0000	
E3	-0.6155	
E4	-0.1070	
F1	0.0677	
F2	-0.4743	
F3	0.0000	
F4	-0.2811	

BLOCK NO = (23.16)   NO OF EVENTS =   1

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0341	
B2	-0.0778	
B3	0.0000	
B4	-0.1169	
C1	-0.0342	
C2	-0.1237	
C3	-0.1142	
C4	0.0000	
D1	-0.0827	
D2	-0.2626	
D3	-0.2133	
D4	-0.1514	
E1	-0.2274	
E2	-0.0745	
E3	-0.4077	
E4	-0.1226	
F1	-0.0200	
F2	-0.3736	
F3	0.0000	
F4	-0.2746	

BLOCK NO = (23.39)   NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0405	0.0000
B2	-0.2114	0.0704
B3	-0.0829	0.1222
B4	0.1299	0.0299
C1	0.0545	0.1082
C2	-0.1718	0.0216
C3	-0.3722	0.0300
C4	0.1681	0.0047
D1	-0.0250	0.0580
D2	-0.3616	0.0753
D3	-0.2412	0.0272
D4	0.0346	0.0047
E1	0.0411	0.0343
E2	-0.1943	0.0946
E3	-0.4698	0.0468
E4	-0.3824	0.0515
F1	0.1771	0.0000
F2	-0.7415	0.0189
F3	-0.6879	0.0041
F4	-0.2993	0.0060

BLOCK NO = (24.15)   NO OF EVENTS = 3

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.1928	0.0686
B2	-0.1064	0.1064
B3	-0.0597	0.0357
B4	-0.1933	0.0595
C1	-0.1712	0.0658
C2	-0.0832	0.1017
C3	-0.1407	0.0602
C4	-0.1357	0.0607
D1	-0.0536	0.0492
D2	-0.2367	0.2410
D3	-0.2109	0.0248
D4	-0.1242	[illegible]
E1	-0.0758	0.1558
E2	-0.1768	0.0464
E3	-0.5901	0.0709
E4	-0.2508	[illegible]
F1	0.0433	0.0000
F2	-0.5057	0.0441
F3	-0.4674	0.1226
F4	-0.3195	[illegible]

BLOCK NO = (24.16) NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.1726	
B2	-0.1395	
B3	-0.1123	
B4	-0.1381	
C1	-0.1208	
C2	-0.1313	
C3	-0.1748	
C4	-0.1872	
D1	-0.0506	
D2	0.0003	
D3	-0.1974	
D4	0.0069	
E1	-0.2388	
E2	-0.1012	
E3	-0.4573	
E4	-0.2237	
F1	0.0588	
F2	-0.4554	
F3	-0.4200	
F4	-0.3207	

BLOCK NO = (25.15) NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.1798	0.0000
B2	-0.0727	0.0642
B3	-0.0245	0.0000
B4	-0.1358	[illegible]
C1	-0.1754	[illegible]
C2	-0.1155	0.0000
C3	-0.1556	0.0797
C4	-0.1334	0.0812
D1	-0.1364	0.1163
D2	-0.2841	0.0868
D3	-0.2361	0.0418
D4	-0.2238	[illegible]
E1	-0.1923	[illegible]
E2	-0.1170	0.1757
E3	-0.3305	0.0000
E4	-0.2370	0.0586
F1	0.0373	0.0000
F2	-0.2730	0.1075
F3	-0.3763	0.0786
F4	-0.4965	[illegible]

BLOCK NO = (25,16)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0747	
B2	-0.0455	
B3	0.0353	
B4	0.0000	
C1	0.0000	
C2	0.0000	
C3	0.0000	
C4	0.0000	
D1	-0.0708	
D2	0.0000	
D3	-0.2046	
D4	0.0000	
E1	0.0000	
E2	0.0000	
E3	-0.3715	
E4	-0.1838	
F1	0.0000	
F2	0.0000	
F3	-0.3547	
F4	0.0000	

BLOCK NO = (29,15)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0854	
B2	-0.1208	
B3	-0.0687	
B4	-0.1147	
C1	-0.1901	
C2	-0.1757	
C3	-0.1715	
C4	-0.0909	
D1	-0.0979	
D2	-0.3041	
D3	-0.1790	
D4	-0.3384	
E1	-0.2498	
E2	-0.2332	
E3	-0.2154	
E4	-0.1417	
F1	-0.1252	
F2	-0.3432	
F3	0.0074	
F4	-0.7850	

BLOCK NO = (30.35) NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0000	
B2	0.0000	
B3	0.0000	
B4	0.1182	
C1	0.1654	
C2	-0.0255	
C3	-0.2714	
C4	0.2435	
D1	0.1464	
D2	-0.2209	
D3	0.0000	
D4	0.0000	
F1	0.1617	
F2	-0.1402	
F3	-0.3816	
F4	-0.1445	
F1	0.1454	
F2	0.0000	
F3	-0.6368	
F4	-0.2631	

BLOCK NO = (31.15) NO OF EVENTS = 3

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0840	0.0932
B2	-0.1518	0.0153
B3	-0.0229	0.0187
B4	-0.0502	0.0471
C1	-0.1572	0.0532
C2	-0.1315	0.1000
C3	-0.1302	0.0257
C4	-0.0670	0.0209
D1	-0.1204	0.0000
D2	-0.2904	0.0000
D3	-0.1480	0.1629
D4	-0.3395	0.0000
F1	-0.3999	0.0111
F2	-0.1903	0.0785
F3	-0.2134	0.2306
F4	-0.1125	[illegible]
F1	-0.2898	0.0000
F2	-0.4354	0.0000
F3	-0.1528	0.0895
F4	-0.9142	0.0236

BLOCK NO = [illegible] NO OF EVENTS = [illegible]

SUBARRAY	MEAN	STD.DEVIATION
[illegible]	[illegible]	
B3	0.0000	
B4	0.0000	
C1	[illegible]	
C2	[illegible]	
C3	-0.1719	
C4	0.2069	
D1	[illegible]	
D2	-0.3659	
D3	0.0000	
D4	-0.0096	
E1	[illegible]	
E2	[illegible]	3
E3	-0.3833	
E4	-0.0431	
F1	[illegible]	
F2	[illegible]	
F3	-0.5426	
F4	-0.3222	

BLOCK NO = (31,36) NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	[illegible]	
B2	-0.0320	
B3	0.1058	
B4	0.2105	
C1	[illegible]	
C2	-0.0752	
C3	-0.1969	
C4	0.2519	
D1	[illegible]	
D2	-0.1500	
D3	0.0000	
[illegible]	[illegible]	
E2	-0.3067	
E3	-0.3217	2
[illegible]	[illegible]	
F1	[illegible]	
F2	-0.5835	
F3	-0.5795	5
F4	[illegible]	

BLOCK NO = (32,35)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0159	
B2	-0.1068	
B3	0.0183	
B4	0.1753	
C1	0.1375	
C2	-0.0535	
C3	-0.1755	
C4	0.2555	
D1	0.0024	
D2	-0.2863	
D3	-0.1516	
D4	0.1317	
F1	0.2184	
F2	-0.2512	
F3	-0.3962	
F4	0.0539	
F1	-0.0229	
F2	-0.5834	
F3	-0.5376	
F4	-0.2195	

BLOCK NO = (33,38)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0000	
B2	0.0000	
B3	0.0000	
B4	0.0000	
C1	0.1646	
C2	-0.1574	
C3	-0.3166	
C4	0.3443	
D1	0.0797	
D2	-0.4239	
D3	0.0005	
D4	0.4066	
F1	0.2303	
F2	-0.3217	
F3	-0.5440	
F4	0.2102	
F1	0.1421	
F2	-0.6889	
F3	-0.7430	
F4	-0.2797	

BLOCK NO = (35,39)   NO OF EVEN[illegible]

SUBARRAY	MEAN	STD.DEVIATION
B1	0.6[illegible]30	
B2	0.0000	
B3	0.0715	
B4	0.2174	
C1	0.2764	
C2	0.0144	
C3	-0.2203	
C4	0.3038	
D1	0.1449	
D2	0.0000	
D3	0.0406	
D4	0.6089	
E1	0.2445	
E2	-0.0392	
E3	0.0000	
E4	0.2615	
F1	0.0563	
F2	-0.4597	
F3	-0.5671	
F4	-0.2032	

2

BLOCK NO = (34,44)   NO OF EVENTS =   1

SUBARRAY	MEAN	STD.DEVIATION
B1	0.3280	
B2	0.0000	
B3	0.0000	
B4	0.2705	
C1	0.0000	
C2	0.3014	
C3	0.0000	
C4	0.2753	
D1	0.0000	
D2	0.0000	
D3	-0.0139	
D4	0.5784	
E1	0.0000	
E2	0.4375	
E3	-0.2470	
E4	[illegible]	
F1	1.0376	
F2	-0.2741	
F3	-0.4831	
F4	0.0000	

BLOCK NO = (35.15)   NO OF EVENTS = 16

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0237	0.0657
B2	-0.2166	0.2714
B3	-0.0675	0.0916
B4	0.073[illegible]	0.0705
C1	-0.0067	0.0567
C2	-0.2890	0.1538
C3	-0.1731	0.0410
C4	0.0739	0.0589
D1	-0.0662	0.0559
D2	-0.3743	0.1124
D3	-0.1702	0.0921
D4	-0.2217	0.1691
E1	-0.3237	0.1698
E2	-0.5136	0.2605
E3	-0.4536	0.2788
E4	-0.0649	0.0556
F1	-0.1360	0.0643
F2	-0.6865	0.1952
F3	-0.2443	0.1448
F4	-0.7830	0.2189

BLOCK NO = (35.16)   NO OF EVENTS = 16

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0513	0.05[illegible]
B2	-0.2635	0.1130
B3	-0.0926	0.0567
B4	0.0802	0.0569
C1	0.0075	0.0461
C2	-0.3097	0.1247
C3	-0.1997	0.0535
C4	0.0408	0.0403
D1	-0.0452	0.0493
D2	-0.3710	0.1106
D3	-0.1878	0.0904
D4	-0.2027	0.1353
E1	-0.2405	0.0895
E2	-0.4621	0.1915
E3	-0.4585	0.1954
E4	-0.0315	0.0831
F1	-0.0815	0.0985
F2	-0.6533	0.0658
F3	-0.2446	0.1221
F4	-0.7699	0.2124

BLOCK NO = [illegible] NO OF [illegible]

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0[illegible]	[illegible]
B2	-0.2999	0.07[illegible]
B3	-0.0894	0.0767
B4	0.0316	0.0634
C1	0.0024	0.06[illegible]
C2	-0.5092	0.0185
C3	-0.2940	0.0148
C4	0.0676	0.0371
D1	-0.0703	0.0[illegible]
D2	-0.4514	0.0000
D3	-0.2272	0.0153
D4	-0.2003	0.0475
E1	-0.2623	[illegible]71
E2	[illegible]	[illegible]
E3	-0.5665	0.0279
E4	-0.0060	0.0658
F1	-0.1144	[illegible]
F2	-0.6319	[illegible]
F3	-0.3523	0.0658
F4	-0.8073	0.8084

BLOCK NO = (37.40) NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	0.1599	
B2	-0.1421	
B3	0.0012	
B4	0.0000	
C1	0.2969	
C2	0.1098	
C3	-0.1493	
C4	0.5402	
D1	[illegible]	
D2	0.0000	
D3	0.0300	
D4	[illegible]	
E1	0.3950	
E2	-0.0597	
E3	-0.1944	
E4	[illegible]	
F1	0.2487	
F2	-0.5860	
F3	-0.5358	
F4	[illegible]	

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3

BLOCK NO = (38.40)   NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0468	0.0031
B2	-0.1561	0.0546
B3	0.0075	0.0499
B4	0.2042	0.0000
C1	0.2643	0.0057
C2	-0.0783	0.1420
C3	-0.1823	0.0738
C4	0.2732	0.0051
D1	0.2725	0.0000
D2	-0.2751	[illegible]
D3	-0.0309	0.0930
D4	0.6218	0.0340
F1	0.3427	[illegible]
F2	-0.1740	[illegible]
F3	-0.1539	0.0000
F4	0.3158	0.0641
F1	0.2457	[illegible]
F2	-0.4428	0.0000
F3	-0.6109	0.0000
F4	0.2187	0.1859

BLOCK NO = (39.39)   NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0939	[illegible]
B2	-0.1821	0.0421
B3	-0.1741	0.0645
B4	0.1513	0.0481
C1	0.2842	[illegible]
C2	0.0040	0.0025
C3	-0.2463	0.0126
C4	0.1391	0.0864
D1	0.2860	0.0500
D2	-0.2847	0.0000
D3	-0.1624	0.0000
D4	0.7334	0.0000
F1	0.7094	[illegible]
F2	-0.1011	0.0594
F3	-0.4436	0.0000
F4	0.1993	[illegible]
F1	0.8189	0.0845
F2	-0.2914	0.0000
F3	0.0164	0.0000
F4	0.2771	0.0042

BLOCK NO = [illegible] NO OF EVENTS = [illegible]

SUBARRAY	MEAN	STD.DEVIATION
B1	0.1392	
B2	-0.0703	
B3	0.0225	
B4	0.2120	
C1	0.3338	
C2	0.0236	
C3	-0.1215	
C4	0.2884	
D1	0.3240	
D2	-0.1001	
D3	-0.0239	
D4	0.7177	
E1	0.5885	
E2	-0.0366	
E3	-0.3245	
E4	0.2798	
F1	0.0000	
F2	-0.4437	
F3	-0.6723	
F4	0.3682	

BLOCK NO = (40,30) NO OF EVENTS = 5

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0089	[illegible]
B2	-0.1643	0.1658
B3	0.0041	0.0326
B4	0.2169	[illegible]
C1	0.2754	[illegible]
C2	-0.0973	0.0413
C3	-0.1623	0.0340
C4	0.2070	[illegible]
D1	0.2346	[illegible]
D2	-0.2858	0.0271
D3	-0.0419	0.0537
D4	[illegible]	[illegible]
E1	0.2783	[illegible]
E2	-0.4534	0.0283
E3	0.0015	0.0380
E4	[illegible]	[illegible]
F1	[illegible]	[illegible]
F2	-0.1531	0.1002
F3	0.0363	[illegible]
F4	[illegible]	[illegible]

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2

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BLOCK NO = (40,31)   NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0589	0.0437
B2	-0.0680	0.1061
B3	0.0330	0.0441
B4	0.2341	0.0522
C1	0.2863	0.0034
C2	-0.0588	0.1473
C3	-0.2066	0.0788
C4	0.2316	0.0067
D1	0.2122	0.0534
D2	-0.3011	0.0000
D3	0.0051	0.0026
D4	0.4654	0.0300
E1	0.4067	0.0000
E2	-0.3796	0.0536
E3	0.0173	0.0521
E4	0.2977	0.0486
F1	0.2871	0.0747
F2	-0.1831	0.0393
F3	0.0488	0.0883
F4	0.0535	0.0160

BLOCK NO = (40,40)   NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION
B1	0.1090	[illegible]
B2	-0.0444	0.0331
B3	-0.0451	0.0111
B4	0.2571	[illegible]
C1	0.3443	[illegible]
C2	0.0227	0.0588
C3	-0.1590	0.0000
C4	0.2936	[illegible]
D1	0.3272	[illegible]
D2	-0.2113	0.0021
D3	-0.0370	0.0201
D4	0.8130	[illegible]
E1	0.6694	[illegible]
E2	-0.1093	0.0000
E3	-0.2489	0.0053
E4	0.2895	[illegible]
F1	0.0000	-0.0000
F2	-0.4490	0.0206
F3	-0.4358	0.0093
F4	0.5794	0.0380

BLOCK NO = (41.28)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0129	
B2	-0.1611	
B3	-0.0157	
B4	0.1864	
C1	0.1567	
C2	-0.1227	
C3	0.0000	
C4	0.2025	
D1	0.1325	
D2	-0.2795	
D3	-0.0417	
D4	0.4110	
F1	0.0000	
F2	0.0000	
F3	0.0000	
F4	0.2892	
F1	0.0000	
F2	-0.1534	
F3	0.1127	
F4	0.0000	

BLOCK NO = (41.29)   NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0270	0.0318
B2	-0.1554	0.0639
B3	-0.0199	0.0197
B4	0.1528	0.0014
C1	0.1799	0.0330
C2	-0.1109	0.0017
C3	-0.1758	0.0053
C4	0.1869	0.0187
D1	0.1911	0.0378
D2	-0.2876	0.0110
D3	-0.0336	0.0070
D4	0.4706	[illegible]
F1	0.1886	0.0177
F2	-0.4130	0.0086
F3	-0.0889	0.0000
F4	0.2445	[illegible]
F1	0.2830	0.1278
F2	-0.1530	0.0459
F3	0.0367	0.0104
F4	-0.1909	[illegible]

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3

BLOCK NO = (41.30)   NO OF EVENTS =   7

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0125	0.0888
B2	-0.1432	0.1457
B3	-0.0449	0.0535
B4	0.2398	0.2620
C1	0.2157	0.1641
C2	-0.1388	0.0929
C3	-0.1938	0.1547
C4	0.2218	0.1713
D1	0.1663	0.0617
D2	-0.2793	0.0702
D3	-0.0253	0.0799
D4	0.3754	0.8400
E1	0.2576	0.1964
E2	-0.3874	0.0229
E3	-0.0257	0.1119
E4	0.2957	0.0457
F1	0.2311	0.2454
F2	-0.1520	0.0449
F3	0.0240	0.0885
F4	-0.0903	0.1126

BLOCK NO = (41.31)   NO OF EVENTS =   7

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0208	0.0428
B2	-0.1945	0.0928
B3	-0.0065	0.0800
B4	0.1786	0.0855
C1	0.2560	0.1076
C2	-0.1086	0.0870
C3	-0.1902	0.1389
C4	0.2306	0.1703
D1	0.1582	0.0765
D2	-0.3220	0.2324
D3	0.0309	0.0365
D4	0.4400	0.2070
E1	0.4120	0.0717
E2	-0.4111	0.1911
E3	0.0514	0.0490
E4	0.3757	0.2035
F1	0.3212	0.1776
F2	-0.1500	0.0792
F3	0.0438	0.0530
F4	-0.0315	0.1073

BLOCK NO = (41,32)   NO OF EVENTS = [illegible]

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0030	0.0395
B2	-0.1894	0.2694
B3	0.0171	0.0369
B4	0.2105	0.2979
C1	0.2887	0.41[illegible]
C2	-0.1385	0.1960
C3	-0.2186	0.3091
C4	0.2605	0.1866
D1	0.2247	0.1793
D2	-0.3839	0.5429
D3	0.0316	0.0853
D4	0.5590	0.4058
F1	0.4985	0.0785
E2	-0.3162	0.2350
F3	0.1130	0.0459
F4	0.4042	0.0899
F1	0.3630	0.2900
F2	-0.1372	0.0286
F3	0.1284	0.1004
F4	0.0337	0.0383

BLOCK NO = (42,31)   NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0513	0.0000
B2	-0.1366	0.0000
B3	0.1112	0.0000
B4	0.2593	[illegible]
C1	0.3372	[illegible]
C2	-0.0354	0.0505
C3	-0.0601	0.0848
C4	0.2896	[illegible]
D1	0.2282	[illegible]
D2	-0.3045	0.0363
D3	0.0754	0.0115
[illegible]	0.5020	[illegible]
[illegible]	0.4173	[illegible]
F2	-0.4869	0.0200
F3	0.0868	0.0136
[illegible]	[illegible]	[illegible]
F1	0.3651	[illegible]
F2	-0.1685	0.0241
F3	0.0915	0.0190
[illegible]	[illegible]	[illegible]

BLOCK NO = (42,32) NO OF EVENTS = 17

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0131	0.0652
B2	-0.1705	0.1792
B3	0.0124	0.0709
B4	0.2353	0.2040
C1	0.3143	0.1717
C2	-0.0690	0.0823
C3	-0.1365	0.1047
C4	0.3004	0.1025
D1	0.1753	0.0872
D2	-0.2925	0.2298
D3	0.1380	0.1084
D4	0.6248	0.3120
F1	0.5805	0.2428
F2	-0.3240	0.1418
F3	0.1147	0.0932
F4	0.4399	0.1419
F1	0.4312	0.1989
F2	-0.1430	0.2133
F3	0.0880	0.0752
F4	0.1087	0.1542

BLOCK NO = (43,24) NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0430	
B2	-0.1024	
B3	0.0597	
B4	0.3011	
C1	0.3395	
C2	0.0000	
C3	-0.1407	
C4	0.2243	
D1	0.1128	
D2	0.0000	
D3	-0.1539	
D4	0.0000	
F1	0.4600	
F2	-0.4504	
F3	-0.2499	
F4	0.2171	
F1	0.0000	
F2	-0.4421	
F3	-0.5458	
F4	-0.0230	

A

BLOCK NO = (43.32)   NO OF EVENTS = 9

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0180	0.0672
B2	-0.0936	0.1046
B3	0.0685	0.0576
B4	0.2098	0.0819
C1	0.2719	0.0635
C2	-0.1010	0.0482
C3	-0.1023	0.0228
C4	0.3312	0.0380
D1	0.1563	0.0547
D2	-0.1883	0.2624
D3	0.1899	0.0483
D4	0.7284	0.2810
E1	0.7864	0.0463
E2	-0.3135	0.0504
E3	-0.0205	0.0593
E4	0.5815	0.0468
F1	0.6735	0.0529
F2	-0.2027	0.1522
F3	-0.0140	0.0642
F4	0.4305	0.0678

BLOCK NO = (43.37)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0712	
B2	-0.0690	
B3	0.0463	
B4	0.0000	
C1	0.3254	
C2	0.0319	
C3	-0.0787	
C4	0.2680	
D1	0.2689	
D2	0.0000	
D3	0.2095	
D4	0.9719	
E1	0.8463	
E2	-0.2473	
E3	0.1703	
E4	0.4192	
F1	0.0000	
F2	-0.0701	
F3	-0.0176	
F4	0.6479	

BLOCK NO = (44.23)   NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0478	0.0028
B2	-0.0572	0.0000
B3	-0.03[illegible]	0.0659
B4	0.2497	0.1095
C1	0.3336	0.0665
C2	-0.0451	0.0076
C3	-0.0955	0.0598
C4	0.1308	0.0155
D1	0.1996	0.013[illegible]
D2	-0.2191	0.0092
D3	-0.1796	0.0270
D4	0.4113	0.0082
E1	0.6517	0.1429
E2	-0.3395	0.0622
E3	-0.2938	0.0268
E4	0.1349	0.0283
F1	0.7450	[illegible]
F2	-0.3123	[illegible]
F3	-0.5222	0.1019
F4	0.0413	0.0000

BLOCK NO = (44.24)   NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0388	[illegible]
B2	-0.0950	0.0495
B3	-0.0468	0.0284
B4	0.0000	0.0000
C1	0.2115	0.0000
C2	-0.1050	0.0072
C3	-0.1333	0.0071
C4	0.1559	[illegible]
D1	0.1705	0.0000
D2	-0.3128	0.0000
D3	-0.2377	0.0638
D4	0.4221	[illegible]
E1	0.5160	[illegible]
E2	-0.3639	0.0291
E3	-0.2283	0.0626
E4	0.0632	0.0000
F1	0.3529	0.0000
F2	-0.3833	0.0000
F3	-0.6937	0.09[illegible]5
F4	-0.0004	0.0000

BLOCK NO = [illegible]   NO OF EVENTS = [illegible]

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0262	
B2	-0.0773	
B3	0.0610	
B4	0.2174	
C1	0.2377	
C2	-0.1502	
C3	-0.1106	
C4	0.2840	
D1	0.1441	
D2	-0.3343	
D3	0.1503	
D4	0.6480	
E1	0.7850	
E2	-0.4479	
E3	-0.1560	
E4	0.5973	
F1	0.7139	
F2	-0.3991	
F3	-0.0914	
F4	0.3879	

BLOCK NO = (44.33)   NO OF EVENTS = 7

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0401	[illegible]
B2	-0.0667	0.0959
B3	0.0900	0.0566
B4	0.1990	[illegible]
C1	0.2597	[illegible]
C2	-0.0811	0.0590
C3	-0.1177	0.0667
C4	0.2967	[illegible]
D1	0.1687	[illegible]
D2	-0.2119	0.1546
D3	0.2346	0.0751
D4	[illegible]	[illegible]
E1	0.8563	[illegible]
E2	-0.2257	0.0368
E3	0.0005	0.0921
E4	[illegible]	[illegible]
F1	0.7824	[illegible]
F2	-0.0239	0.0885
F3	-0.0182	0.0435
F4	[illegible]	[illegible]

BLOCK NO = (44.36)   NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0285	0.0664
B2	0.0281	0.0780
B3	0.0308	0.0000
B4	0.2114	0.0025
C1	0.3097	0.0454
C2	0.0349	0.0024
C3	-0.0471	0.0414
C4	0.2332	0.0000
D1	0.2702	0.0278
D2	-0.1509	0.0000
D3	0.1977	0.0420
D4	0.6985	0.0000
E1	0.9643	0.0137
E2	-0.1428	0.0161
E3	0.2771	0.1007
E4	0.5165	0.0030
F1	0.6945	0.0000
F2	-0.0567	0.1392
F3	0.0095	0.0000
F4	0.6947	0.1169

BLOCK NO = (44.37)   NO OF EVENTS = 10

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0310	0.0598
B2	-0.0837	0.0782
B3	-0.0703	0.1238
B4	0.1347	0.0852
C1	0.2945	0.1442
C2	-0.0071	0.0864
C3	-0.0977	0.0434
C4	0.2614	0.0715
D1	0.2553	0.0715
D2	-0.1643	0.0875
D3	0.1243	0.0857
D4	0.6876	0.3796
E1	0.8544	0.0969
E2	-0.2211	0.0522
E3	0.1562	0.1382
E4	0.3715	[illegible]
F1	0.8075	0.4350
F2	-0.1050	0.0674
F3	-0.0262	0.0754
F4	0.5497	0.13[illegible]

SUBARRAY	MEAN	STD.DEVIATION
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
B3	-0.0208	0.0000
B4	0.0000	-0.0000
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
C3	-0.1628	0.2302
C4	-0.0199	0.0709
[illegible]	0.1887	[illegible]
[illegible]	-0.1922	[illegible]
D3	-0.3023	0.2216
D4	0.2784	0.2204
[illegible]	[illegible]	[illegible]
[illegible]	-0.2901	[illegible]
E3	-0.2231	0.0896
E4	0.1427	0.0527
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
F3	-0.4195	0.3434
F4	0.0478	0.0525

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4

3

BLOCK NO = (45.32)   NO OF EVENTS =   3

SUBARRAY	MEAN	STD.DEVIATION
B1	[illegible]	[illegible]
B2	-0.0968	0.1548
B3	0.0235	0.0497
[illegible]	0.1261	[illegible]
[illegible]	[illegible]	[illegible]
C2	0.0000	-0.0000
C3	-0.0181	0.0000
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
D2	-0.1402	0.1452
D3	0.2749	0.2776
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
E2	-0.2671	[illegible]
E3	-0.0354	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
F2	-0.1545	0.1607
F3	0.0453	[illegible]

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3

3

BLOCK NO = (45.34)   NO OF EVENTS = 4

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0395	0.0407
B2	-0.0395	0.0366
B3	0.0815	0.0792
B4	0.1980	0.1416
C1	0.2417	0.0353
C2	-0.0340	0.0758
C3	0.0043	0.0414
C4	0.2804	0.0314
D1	0.1634	0.0173
D2	-0.1736	0.1269
D3	0.2255	0.0331
D4	0.6510	0.0695
E1	0.7920	[illegible]
E2	-0.1630	[illegible]
E3	0.0478	0.1161
E4	0.5047	0.0431
F1	0.7502	0.0590
F2	0.1720	0.1174
F3	0.0393	0.0567
F4	0.6584	0.0509

BLOCK NO = (45.36)   NO OF EVENTS = 3

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0743	[illegible]
B2	-0.0126	0.0000
B3	0.0598	0.0672
B4	0.1466	0.1518
C1	0.2745	0.2755
C2	0.0377	0.0450
C3	-0.0521	0.0408
C4	0.2726	0.0435
D1	0.2233	0.0548
D2	-0.1022	0.1040
D3	0.2414	0.0804
D4	0.6655	0.0000
E1	0.8128	0.0204
E2	-0.2047	0.0000
E3	0.1378	0.1518
E4	0.4933	0.0702
F1	0.7658	[illegible]
F2	0.0822	0.0000
F3	-0.0060	0.0000
F4	0.7925	0.0000

BLOCK NO = [illegible]

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0097	
B2	[illegible]	
B3	0.0878	
B4	0.1477	
C1	0.0000	
C2	0.0240	
C3	-0.0565	
C4	0.0000	
D1	[illegible]	
D2	[illegible]	
D3	0.2577	
D4	0.6291	
E1	0.0000	
E2	-0.2059	
E3	0.0239	
E4	0.4492	
F1	0.7917	
F2	0.0579	
F3	0.0098	
F4	0.5653	

BLOCK NO = (47, 5)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0071	
B2	-0.0046	
B3	-0.0200	
B4	[illegible]	
C1	[illegible]	
C2	-0.1807	
C3	-0.0716	
C4	[illegible]	
D1	[illegible]	
D2	-0.0022	
D3	0.1532	
D4	[illegible]	
E1	[illegible]	
E2	-1.0024	
E3	-0.2166	
E4	[illegible]	
F1	0.0000	
F2	-0.9968	
F3	0.2320	
F4	[illegible]	

BLOCK NO = (47.34)   NO OF EVENTS = 3

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0450	0.0420
B2	-0.0066	0.0709
B3	0.0343	0.0093
B4	0.1161	0.0054
C1	0.1580	0.0613
C2	-0.0255	0.0563
C3	-0.0343	0.0902
C4	0.2002	0.0324
D1	0.0994	0.0493
D2	-0.0562	0.1137
D3	0.1762	0.0420
D4	0.5295	0.0271
F1	0.5644	0.0311
F2	-0.1367	0.0608
F3	-0.0539	0.0752
F4	0.3203	0.0669
F1	0.7727	0.0305
F2	0.1695	[illegible]
F3	-0.0949	0.0494
F4	0.4381	0.0434

BLOCK NO = (47.35)   NO OF EVENTS = 3

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0295	[illegible]
B2	-0.0436	0.0238
B3	-0.0076	0.0951
B4	0.0913	[illegible]
C1	0.1083	[illegible]
C2	0.0093	0.0942
C3	-0.0462	0.0878
C4	0.1235	[illegible]
D1	0.0908	[illegible]
D2	-0.0247	0.0418
D3	0.1904	0.0455
D4	0.4920	[illegible]
F1	0.6182	0.1116
F2	-0.1449	0.1433
F3	-0.0279	0.0860
F4	0.3202	0.0498
F1	[illegible]	[illegible]
F2	0.1299	0.1026
F3	-0.0672	0.0922
F4	0.3998	0.4184

[illegible]

SUBARRAY	MEAN	STD.DEVIATION
B1	[illegible]	
B2	[illegible]	
B3	-0.0127	
B4	0.0873	
C1	[illegible]	
C2	[illegible]	
C3	-0.1300	
C4	0.2379	
D1	[illegible]	
D2	-0.0269	
D3	0.1745	
D4	0.5591	
E1	0.0000	
E2	0.0000	
E3	0.0000	
E4	0.0000	
F1	0.0000	
F2	0.0000	
F3	0.0000	
F4	0.0000	

BLOCK NO = (48,34)   NO OF EVENTS =   3

SUBARRAY	MEAN	STD.DEVIATION
B1	[illegible]	[illegible]
B2	-0.0097	0.3295
B3	0.0325	[illegible]
B4	[illegible]	[illegible]
C1	[illegible]	[illegible]
C2	0.0086	0.0358
C3	-0.0512	0.1333
C4	0.2119	[illegible]
D1	0.1479	[illegible]
D2	0.0124	0.0000
D3	0.2140	0.2166
D4	[illegible]	[illegible]
E1	[illegible]	[illegible]
E2	0.0711	0.0915
E3	-0.0920	0.0989
E4	[illegible]	[illegible]
F1	[illegible]	[illegible]
F2	0.0829	0.0622
F3	-0.2405	0.2607
F4	[illegible]	[illegible]

BLOCK NO = (49.23)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0573	
B2	-0.0445	
B3	0.2025	
B4	0.1661	
C1	0.2689	
C2	0.2353	
C3	0.0000	
C4	0.0000	
D1	0.0121	
D2	0.0240	
D3	0.0000	
D4	0.2824	
E1	0.2410	
E2	0.2659	
E3	0.0853	
E4	-0.2168	
F1	0.1578	
F2	0.1738	
F3	0.2571	
F4	-0.0502	

BLOCK NO = (49.25)   NO OF EVENTS = 3

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0038	0.0865
B2	-0.0157	0.1250
B3	0.0621	0.0441
B4	0.0555	0.0756
C1	0.0748	0.0445
C2	-0.1404	0.1464
C3	-0.0378	0.0309
C4	0.1532	0.0505
D1	-0.0265	0.0749
D2	-0.0944	0.1043
D3	0.1666	0.0377
D4	0.5958	0.5958
E1	0.6710	0.6726
E2	-0.1555	0.4114
E3	-0.1140	0.0789
E4	0.2281	0.1681
F1	0.4044	0.4366
F2	-0.2338	0.6426
F3	-0.0201	0.2398
F4	0.1897	0.2425

BLOCK NO = (49.33)   NO OF EVENTS = 5

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0134	[illegible]
B2	-0.0732	[illegible]
B3	0.0166	0.0193
B4	0.1146	0.1190
C1	0.1527	[illegible]
C2	-0.0310	0.0670
C3	-0.1011	0.1157
C4	0.1927	0.0398
D1	0.1399	0.1064
D2	-0.1168	0.0000
D3	0.1681	0.0873
D4	0.5502	0.5505
E1	0.5765	[illegible]
E2	-0.0142	[illegible]
E3	-0.1497	0.0328
E4	0.2665	0.0611
F1	0.6810	[illegible]
F2	-0.0038	[illegible]
F3	-0.3205	0.1860
F4	0.5514	0.0977

11

3

BLOCK NO = (49.34)   NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0992	0.0000
B2	-0.0812	0.0000
B3	-0.0172	0.0000
B4	0.0071	0.0000
C1	0.1756	[illegible]
C2	0.0109	0.0000
C3	-0.2956	0.0000
C4	0.1872	[illegible]
D1	0.1522	[illegible]
D2	-0.0378	0.0000
D3	0.1708	0.0000
D4	[illegible]	[illegible]
E1	0.6514	[illegible]
E2	-0.0035	0.0508
E3	-0.0756	0.0993
E4	0.2833	[illegible]
F1	0.5934	[illegible]
F2	0.0671	0.0838
F3	-0.4074	0.0000
[illegible]	[illegible]	[illegible]

2

2

2

BLOCK NO = (49,48) NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0000	
B2	0.0000	
B3	0.0000	
B4	0.0000	
C1	0.2945	
C2	-0.0469	
C3	-0.0768	
C4	0.0000	
D1	0.1951	
D2	0.0000	
D3	0.0078	
D4	0.3660	
E1	0.6324	
E2	0.0663	
E3	0.6759	
E4	0.0000	
F1	0.5912	
F2	0.0000	
F3	0.0000	
F4	0.0000	

BLOCK NO = (50,29) NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0994	
B2	0.0000	
B3	0.0471	
B4	0.0771	
C1	0.0651	
C2	0.0000	
C3	-0.0585	
C4	0.1464	
D1	-0.0758	
D2	-0.1202	
D3	0.1653	
D4	0.5208	
E1	0.6021	
E2	-0.3851	
E3	-0.1539	
E4	0.3052	
F1	0.5652	
F2	-0.4508	
F3	-0.1377	
F4	0.2830	

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BLOCK NO = (50,31)   NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION	
B1	-0.0899	0.0792	T
B2	-0.0610	0.1695	
B3	0.0048	0.0383	
B4	0.0265	0.0488	
C1	0.1402	0.0390	
C2	-0.0426	0.0000	
C3	-0.0096	0.0378	3
C4	0.1889	0.0033	
D1	0.0166	0.0241	
D2	-0.1359	0.0028	
D3	0.2431	0.0000	
D4	0.5156	0.0000	
E1	0.6510	0.0548	
E2	-0.1119	0.0006	
E3	-0.2352	0.0000	1
E4	0.2219	0.0911	
F1	0.8459	[illegible]	
F2	-0.0282	0.0116	
F3	-0.2943	0.0000	3
F4	0.6950	0.0109	

BLOCK NO = (50,32)   NO OF EVENTS = 6

SUBARRAY	MEAN	STD.DEVIATION	
B1	-0.1232	0.1088	
B2	-0.0182	0.0522	
B3	-0.0125	0.0727	
B4	0.0913	0.0033	
C1	0.0250	[illegible]	
C2	-0.0102	0.0697	
C3	-0.0707	0.0926	6
C4	0.1715	[illegible]	
D1	0.0525	[illegible]	
D2	-0.1308	0.1675	
D3	0.1775	0.1731	
D4	[illegible]	[illegible]	
E1	0.5944	[illegible]	
E2	-0.1419	0.1260	4
E3	-0.0889	0.0564	
E4	[illegible]	[illegible]	
F1	0.6629	0.5415	
F2	-0.0321	0.1288	
F3	-0.2088	0.0769	3
F4	[illegible]	[illegible]	

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BLOCK NO = (51,26)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0000	
B2	-0.1588	
B3	0.0366	
B4	0.0000	
C1	-0.0066	
C2	0.0000	
C3	0.0000	
C4	0.1659	
D1	-0.1315	
D2	0.0000	
D3	0.1405	
D4	0.4534	
E1	0.0000	
E2	-0.3840	
E3	-0.2144	
E4	0.2957	
F1	0.0000	
F2	-0.5149	
F3	-0.1105	
F4	0.0000	

2

BLOCK NO = (51,30)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0325	
B2	-0.0956	
B3	0.1043	
B4	0.1641	
C1	-0.0815	
C2	0.0687	
C3	0.0215	
C4	0.1339	
D1	0.0835	
D2	-0.0870	
D3	0.1602	
D4	0.5062	
E1	0.6252	
E2	-0.1217	
E3	-0.0408	
E4	0.2961	
F1	0.8394	
F2	0.0607	
F3	-0.0013	
F4	0.7239	

3

2

BLOCK NO = (52,28)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.0779	
B2	-0.0237	
B3	0.0885	
B4	0.0516	
C1	0.0072	
C2	-0.0778	
C3	-0.0310	
C4	0.1572	
D1	-0.0364	
D2	-0.1993	
D3	0.1914	
D4	0.5007	
E1	0.6030	
E2	-0.1135	
E3	-0.1995	
E4	0.2912	
F1	0.0000	
F2	-0.0819	
F3	0.0438	
F4	0.5560	

BLOCK NO = (52,30)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0000	
B2	0.0000	
B3	0.0000	
B4	0.0000	
C1	0.0571	
C2	-0.0996	
C3	0.0000	
C4	0.1521	
D1	0.0281	
D2	-0.1669	
D3	0.1644	
D4	[illegible]	
E1	[illegible]	
E2	0.0000	
E3	-0.2135	
E4	[illegible]	
F1	0.6791	
F2	0.0650	
F3	-0.0245	
F4	[illegible]	

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BLOCK NO = (53,23)   NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.1614	
B2	0.0314	
B3	0.0961	
B4	0.1673	
C1	0.0291	
C2	-0.0388	
C3	0.0505	
C4	0.1371	
D1	-0.1025	
D2	0.0000	
D3	0.2123	
D4	0.5036	
E1	0.4237	
E2	-0.2686	
E3	-0.1469	
E4	0.2507	
F1	0.1564	
F2	-0.3000	
F3	-0.0011	
F4	0.2905	

BLOCK NO = (53,24)   NO OF EVENTS = 2

SUBARRAY	MEAN	STD.DEVIATION
B1	0.0000	-0.0000
B2	0.0000	-0.0000
B3	0.1131	0.0000
B4	0.0814	0.0000
C1	0.0089	[illegible]
C2	-0.0188	0.0034
C3	0.0460	0.0286
C4	0.1546	0.0032
D1	-0.1622	0.0000
D2	-0.1911	0.0107
D3	0.2184	0.0454
D4	0.4913	[illegible]
E1	0.3793	[illegible]
E2	-0.3902	0.0145
E3	-0.0911	0.0904
E4	0.2525	[illegible]
F1	0.0000	-0.0000
F2	-0.3255	0.0000
F3	-0.0605	0.0570
F4	0.4269	0.0520

BLOCK NO = (56.22) NO OF EVENTS = [illegible]

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.1780	[illegible]
B2	-0.0647	0.0709
B3	0.0718	0.0563
B4	0.0440	0.0353
C1	-0.0196	[illegible]
C2	-0.0728	0.0571
C3	0.0227	0.0495
C4	0.1568	0.0067
D1	-0.1618	0.0204
D2	-0.0980	0.0996
D3	0.1687	0.0701
D4	0.3619	0.0844
E1	0.3212	[illegible]
E2	-0.3871	[illegible]
E3	-0.0152	0.0302
E4	0.1736	0.0126
F1	-0.0821	[illegible]
F2	-0.1068	[illegible]
F3	0.1329	0.0266
F4	0.0907	0.1185

BLOCK NO = (58. 5) NO OF EVENTS = 1

SUBARRAY	MEAN	STD.DEVIATION
B1	-0.1776	
B2	-0.1702	
B3	-0.1419	
B4	0.0000	
C1	-0.1001	
C2	0.0000	
C3	-0.2424	
C4	0.0066	
D1	-0.2788	
D2	-0.1924	
D3	-0.0079	
D4	[illegible]	
E1	0.0865	
E2	-0.7921	
E3	0.0945	
E4	0.3637	
F1	-0.6256	
F2	-0.7395	
F3	-0.1112	
F4	0.3082	

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APPENDIX B

CORRECTIONS FOR DEPARTURES FROM SPACE STATIONARITY WHEN COMPUTING WAVENUMBER SPECTRA

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APPENDIX B

CORRECTIONS FOR DEPARTURES FROM SPACE STATIONARITY WHEN COMPUTING WAVENUMBER SPECTRA

The assumption of space stationarity necessary for the computation of meaningful wavenumber spectra may not prove to be valid for large-diameter arrays such as LASA. Departures from the assumed plane wavefront of constant waveform moving at constant velocity may be due to two primary factors: the first is instrument response variations and should be independent of wavenumber; the second is the effect introduced by different crustal paths and different seismometer-to-earth couplings. Upper mantle inhomogenieties, due to variations in thickness and composition, will probably be a function of wavenumber. If the total effect of these two factors can be determined theoretically or empirically, corrections for departures from space stationarity may be easily made as follows.

Let $H_j(w, \vec{k})$ be the transfer function of the filter which equalizes the j^{th} seismometer (or subarray) to the r^{th} or reference seismometer (or subarray). To compute the power density at frequency w and wavenumber $\vec{k}$, the matrix Φ of auto- and crosspower spectra should be premultiplied by T and postmultiplied by T* as shown:

$$\begin{bmatrix} H_1(w,\vec{k}) & 0 & \cdots & 0 \\ 0 & H_2(w,\vec{k}) & \cdots & 0 \\ \vdots & \vdots & & \vdots \\ 0 & 0 & \cdots & H_N(w,\vec{k}) \end{bmatrix} \begin{bmatrix} \Phi_{11}(w) & \Phi_{12}(w) & \cdots & \Phi_{1N}(w) \\ \Phi_{21}(w) & \Phi_{22}(w) & \cdots & \Phi_{2N}(w) \\ \vdots & \vdots & & \vdots \\ \Phi_{N1}(w) & \Phi_{N2}(w) & \cdots & \Phi_{NN}(w) \end{bmatrix} \begin{bmatrix} H_1^*(w,\vec{k}) & 0 & \cdots & 0 \\ 0 & H_2^*(w,\vec{k}) & \cdots & 0 \\ \vdots & \vdots & & \vdots \\ 0 & 0 & \cdots & H_N^*(w,\vec{k}) \end{bmatrix} = T \Phi T^*$$

When computing high-resolution wavenumber spectra (estimating the signal at location j) for the spatially random signal model case, the matrix equation solved for the filter responses $F_1(w)$, $F_2(w)$, ..., $F_n(w)$ is

$$F^* = \Sigma^{-1} \psi$$

where

$$\Sigma = \begin{bmatrix} \Phi_{11}(w) + \dfrac{K(w)}{|H_1(w)|^2} & \Phi_{12}(w) & \cdots & \Phi_{1N}(w) \\ \Phi_{21}(w) & \Phi_{22}(w) + \dfrac{K(w)}{|H_2(w)|^2} & \cdots & \Phi_{2N}(w) \\ \vdots & \vdots & & \vdots \\ \Phi_{N1}(w) & \Phi_{N2}(w) & \cdots & \Phi_{NN}(w) + \dfrac{K(w)}{|H_N(w)|^2} \end{bmatrix}$$

$$\psi = \begin{bmatrix} 0 \\ \vdots \\ 0 \\ \dfrac{K(w)}{|H_j(w)|^2} \\ 0 \\ \vdots \\ 0 \end{bmatrix} \qquad F^* = \begin{bmatrix} F_1^*(w) \\ F_2^*(w) \\ \vdots \\ F_N^*(w) \end{bmatrix}$$

To correct for departures from space stationarity, we should solve the matrix equation

$$T \Sigma T^* F_c^* = H_j^*(w)\, T\psi \qquad \text{(B-1)}$$

or

$$F_c^* = H_j^*(w)\, [T^*]^{-1} \Sigma^{-1} T^{-1} T\psi \qquad \text{(B-2)}$$

$$F_c^* = H_j^*(w)\, [T^*]^{-1} \Sigma^{-1} \psi = H_j^*(w)\, [T^*]^{-1} F^*$$

Thus, the corrected filter responses may be obtained from the uncorrected filter responses from Equation B-2 more simply than through the solution of Equation B-1.

A similar result is obtained for the multichannel Markov case for the correction to the spatial prediction filter responses. The equation to be solved for the filter to predict the N+1th channel now is

$$T\Phi T^* F_c^* = H_{N+1}{}^*(w)\, T\Gamma$$

where

$$\Gamma = \begin{bmatrix} \Phi_{1,N+1}(w) \\ \Phi_{2,N+1}(w) \\ \vdots \\ \Phi_{N,N+1}(w) \end{bmatrix}$$

Therefore,

$$F_c^* = [T^*]^{-1}\,\Phi^{-1}\,T^{-1}\,T\Gamma\,H_{N+1}^*(w) = H_{N+1}^*(w)\,[T^*]^{-1}\,\Phi^{1}\,\Gamma$$

or

$$F_c^* = H_{N+1}^*(w)\,[T^*]^{-1}\,F^*$$

where

$$F^* = \Phi^{-1}\,\Gamma$$

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Texas Instruments Incorporated Science Services Division P.O. Box 5621, Dallas, Texas 75222	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP ———

3. REPORT TITLE
LARGE-ARRAY SIGNAL AND NOISE ANALYSIS — Special Scientific Report No. 15
TRAVELTIME ANALYSIS FOR LASA

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Special Scientific

5. AUTHOR(S) (First name, middle initial, last name)
Peter R. Fenner

6. REPORT DATE 20 December 1967	7a. TOTAL NO. OF PAGES 98	7b. NO. OF REFS 3
8a. CONTRACT OR GRANT NO. AF 33(657)-16678 b. PROJECT NO. VT/6707 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) ——— 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) ———	

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11. SUPPLEMENTARY NOTES ARPA Order No. 599	12. SPONSORING MILITARY ACTIVITY Air Force Technical Applications Center VELA Seismological Center Headquarters, USAF, Washington, D.C.

13. ABSTRACT
The This report investigates practical aspects of generating high-resolution wavenumber spectra using subarray outputs of the Montana LASA. Especially studied are the variability of traveltime anomalies as a function of wavenumber, spectral window effect on crosspower estimates due to moveout across the array, and tradeoffs involved in a finite-length transform of array data. From this investigation, it is concluded that current data are insufficient to define a scheme adequately to correct wavenumber spectra calculations for traveltime anomalies. Also, because subarrays on the E and F rings of LASA generally exhibit larger traveltime residuals and less waveform similarity than do subarrays of the inner rings, subarrays on the E and F rings will not be included in high-resolution f-$\vec{k}$ spectra calculations. ( )

DD FORM 1 NOV 65 1473

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Large-Array Signal and Noise Analysis						
Traveltime Analysis						
High-Resolution Wavenumber Spectra						
Spectral Window Effects						